LIGHT AS A FORM OF VISUAL LANGUAGE

IN EDUCATIONAL SPACES

by Stavroula Angelaki

Light as a form of visual language in educational spaces

- Creating schedules for daily activities -

Master Thesis

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Abstract:

Daylight regulates humans' activities, inner biological clocks and circadian rhythms acting as an external natural clock. Natural light is an essential environmental factor providing time orientation, while at the same time covering fundamental biological needs. Human activity has evolved based on natural light patterns. In the following dissertation, the way light can be used as a means of dialogue between space and the user is investigated. Artificial light can be used as an indicator of change in space, highlighting the daily schedule and activities which take place in it. The developed theoretical background through bibliographic research is used as a foundation for the establishment of a design framework leading to a variety of proposals. The resulted designs are based on the dominant spatial elements that define the identity and function of the space, taking into consideration the existing lighting conditions.

Contents

Preface

This thesis is made as a completion of the master education in Lighting Design at Aalborg University of Copenhagen. The purpose of this dissertation is to introduce and demonstrate innovative ways of using lighting in interior spaces as a form of visual communication while enhancing time orientation throughout the day.

Several persons have contributed to an academic and practical level for the realisation of this thesis. I would, therefore, firstly l ike t o t hank m y s upervisor Georgios Triantafyllidis for his dedicated support and guidance, as he continuously provided encouragement and was always willing to assist in any way he could throughout the thesis. I would also like to thank the professors of the study program for guiding and accompanying me on this light journey.

Finally, I must express my very profound gratitude to my parents and friends for providing me with support and continuous encouragement, and most importantly, my boyfriend, for always standing by my side throughout the process of writing this thesis.

Aalborg University, May 28, 2020

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Chapter 1

Introduction

> *"The 24-hour lightdark cycle is the most important environmental time signal." (Lockley S.W. et al., 2012, p.41)* [48]

Natural light is a fundamental factor for humans' well being. People nowadays spend even more time in interior spaces due to the nature of their jobs and responsibilities. The modern pace and way of life are linked even more with built space, compared to earlier times [4]. Therefore the need for a holistic design of interior spaces and the creation of a spatial dialogue is more imperative than ever. Recent research has revealed the necessity of natural light and the importance of contact both with the exterior environment and daylight. As Lockley underlines, light is an essential environmental time signal and based on Descottes, the presence of light and shadows is related to orientation [15]. The changes in natural light throughout the day indicate the passage of time, but on a bigger scale, also underline the passage of months and seasons [48]. Light is a dynamic component which changes continuously in nature; therefore, this characteristic is essential to exist as a form of lighting design in interior spaces.

The main goal of this thesis is the implementation and transfer of these light principles in the interior space to enhance the way time passes and underline this connection between exterior and interior space. The ever-changing character of light and information it provides needs to be the foundation of lighting design in interior space. The design of each space follows specific requirements linked to its use and the needs of its users. The variety of activities each space hosts can set the basis for the lighting design, making light a dynamic component which signifies the change in space's use. In the same way, light changes in nature, electric light can also be altered based on the course of time and activities that take place in interior spaces. This though led in the definition of the following question that formed the foundation of the thesis.

How can **light** act as an **indicator** of **change** in space?

The answer to this question was investigated through an extensive literature review leading to the formation and proposal of a design framework. The thesis focuses on educational spaces, and specifically primary schools since the essential elements during the analysis are the human scale, and the way perception and vision are affected by it. Educational spaces are essential since children use them daily, but also because of their function and symbolism as places of knowledge. Lighting is a crucial environmental factor, which affects students' well-being and performance. The proposed framework is based upon the various presented theories and is further applied to a case study. The spatial and light analysis, along with the activities taking place in the investigated spaces, are combined and result in multiple lighting design proposals for each space.

Chapter 2

Methods

A combination of different methods was used during this thesis for the establishment of a theoretical framework. The created framework acted as the basis for further development. The literature review allowed the analysis of various topics leading to the main points and theories used in the process. The principles of design thinking were taken into consideration as the central aspect of the thesis is the design of a proposal that follows the user's needs and requirements. A case study was used for the application and further explanation of the proposed design framework. The use of different software allowed the creation of simulations depicting the proposed designs. At the same time, different software was used as a tool for the analysis of the existing lighting situation.

2.1 Literature review

The literature review is the cornerstone of the study since it creates the basis for further investigation and development of ideas. The theoretical background consists of two parts. The first one is related to the background or initial research, leading to the research question. The second part focuses on the definition of terms and further analysis of the primary notions stated in the research question.

The theoretical part focuses on the investigation of semiotics and visual language in an attempt of applying their principles into lighting design. The investigation of lighting as a form of symbol or indicator in space was the core around which the theory evolved. The second part of the theory was human-centred since the analysis focused on the human scale, and the way it affects perception and vision. Theories regarding visual development and spatial cognition were analysed, and the main points were extracted to be further used as success criteria and guidelines during the design process.

Existing theories regarding design, perception and visual development were investigated and then combined to result in a theory-based model of design investigation. This model incorporates spatial and lighting elements, and through their combination aims in creating a lighting proposal that co-exists with the existing elements of space in

harmony, while having a different functionality from the ceiling lighting. The literature review is fundamental since it is used to justify and strengthen the choices made in the course of the thesis. It is also vital for the evaluation of the proposed design framework and the resulting design proposals.

2.2 Design thinking

> *Design is a creative activity whose aim is to establish the multi-faceted qualities of objects, processes, services and their systems in whole life cycles. Therefore, design is the central factor of innovative humanisation of technologies and the crucial factor of cultural and economic exchange. (Koskinen, 2013, p.18)* [40]

Design thinking is a research-based process of working with data based on users' needs and set requirements [7]. It is a human-centred approach used in various areas of design, such as product and service design [90]. The cornerstone of this process is the combination of knowledge deriving from various scientific fields, such as behavioural and social sciences.

> *...a methodology that imbues the full spectrum of innovation activities with a human-centered design ethos. (Brown, 2008, p.1)* [81]

According to Tim Brown, design thinking is a process leading to innovative solutions by following the set guidelines of users' needs. This process is linked to the profound understanding and analysis of everyday problems by investigating the users' background and culture. Through design thinking, new alternatives emerge, leading to designs that embody stories with which users can empathise [70]. The principles of this process are inspiration, ideation and implementation. The definition of an existing problem is the starting point of the process, while in the course of the analysis, the investigation (ideation) of possible solutions is discussed. Ideation is the part where brainstorming takes place, resulting in multiple solutions. The analysis of the possible solutions leads to a dominant proposal. The proposal needs to be tested through the creation of a prototype. The testing process results in changes in the initial proposal and the implementation of the testing results in the design. The feedback from the testing phase leads in the final design proposal. The prototype and testing phase are parts of an iterative process since there are always ways a design proposal can be ameliorated. The number of prototypes and tests performed depends on the time frame of each project [81].

Design thinking is based on interdisciplinarity since it combines various domains of research, design and social sciences. It is a process that focuses on the human aspect and point of view, while at the same time incorporates groundbreaking thinking.

2.3 Case study

A case study which resulted in the investigation of two separate spaces was used as an example of the way the proposed design framework can be applied. The case study concerned a primary school in Athens, Greece and the examination of spatial and lighting characteristics led in various design proposals for each space. The choice of the specific case study is due to the focus in educational spaces and the analysis of users' scale as a core element for spatial and light perception.

2.4 Simulations

A series of software was used in the course of the study for illustration and light investigation. Separate software was used for light analysis, referring to either natural or electric light. The investigation of natural light was performed through the use of SketchUp since it allows the geolocation of the 3d model, and therefore, the exact orientation, shadows and daylight intake can be illustrated. Dialux was used for the simulation of the existing electric light, even though the proposal phase did not require dialux simulations.

For the visualisation of the proposal, SketchUp and V-ray were used. This software allowed the modulation and alteration of the light variables, based on the proposal's needs. The simulation phase allowed the description and visualisation of the proposed design and its further evaluation based on the set design guidelines and success criteria.

Chapter 3

Background research

The following chapter consists of the initial research that resulted in the definition of the research question. The theoretical background was analysed and the main topics of the analysis derived from this process. The introduction of the main tools takes place, and a clarification of the way each one is being used further in the process is stated.

3.1 Semiotics

> *Semiotics, also called semiology, the study of signs and sign-using behaviour. (The Editors of Encyclopaedia Britannica, 2020)[71]*

Semiotics is the science that analyses the relations between signs, meanings and behaviours. Through the science of semiotics, the use of symbols and signs is analysed. This knowledge can be a tool for establishing relations and meanings between signs and users. Semiotics is widely used in design as it enhances the creation of a link between the user and the proposed design [92] [13].

The founder of this study is the swiss linguist Ferdinand de Saussure according to whom semiotics is analysed in parallel to the language system. Semiotics defines the link created between a sign and a concept. Ferdinand de Saussure points out the elements of the concept, labelled as signified, and sound-image labelled as the signifier. The combination of the concept and sound-image results in the definition of a sign [69].

Based on de Saussure the linguistic sign has two main principles, the arbitrary nature of the sign and the linear nature of the signifier. The first principle indicates the range of different meanings a sign can bare. Having as a reference point the way language is used in communication de Saussure highlights that the same sign can be used for providing different kinds of information, in the same way, a word can bare multiple meanings in different sentences. The second principle is linked to the fact that the signifier, which is the sound-image, is processed primarily through auditory perception. The dimension of time defines auditory signifiers. Therefore they have a linear nature.

Apart from de Saussure's approach, another significant theory belongs to the American philosopher Charles Sanders Pierce. Pierce categorised the signs into three different types which are the icon, symbol and index. Pierce analysed and developed his theory of semiotics through the prism of philosophy. Pierce supported that people communicate both by using signs and by assigning meanings to anything that surrounds them. Saussure, on the other hand, mentioned that signs are products of the human mind that expressed through the use of language [95]. Regardless of the differences between these two points of view, the common ground for these theories is that the use of signs and symbols is fundamental for communication. Furthermore, as Umberto Eco highlights in his book "A theory of semiotics" :

> *"...semiotics is destined to overcome one of its natural boundaries and to become not only the theory of codes and sign production but also of the 'deep' individual origins of any 'wish to produce signs'." (Eco,p.315)*

while further stating that code and sign production are processes performed subconsciously in an attempt for communication [18].

Eco states that the complexity of each language is reflected upon the way the same signs are interpreted, taking into account the cultural background of every individual. In other words, he suggests the existence of infinite meanings and ways of using the same sign in a different context in terms of culture and language [17].

3.2 Visual language

The term visual language has significantly taken ground during the past decades since it has become an essential part of everyday life. Visual language and communication are a fundamental part of the digital world and can be seen both in urban public spaces as well as interior spaces. Visual communication can be performed through images in the form of advertisement, education and recreation [29]. Even though most people are not familiar or educated regarding visual literacy, everyday experience is a keystone to decoding and analysing basic visual signs. The link between semiotics and visual languages rests in the use of signs which bare specific definitions that are collectively recognised. An example of those signs is the use of specific icons in mobile phones and applications, such as the "save" button. Even though the symbol represents an outdated product, everyone is aware of the meaning it bears. [34].

The term "visual language" is used in various domains; thus, it holds slightly different meanings regarding the specification of each domain. For UI designers visual language is the guideline for layout design as for researchers a graph can be a form of visual language.[20] Wittgenstein, on the other hand, in his "Philosophical Investigations" supports that facial expressions and gestures are also a form of visual language and therefore forms of communication [50]. One could support that all those examples

are a form of visual language, which is the reason that according to this study, a slightly different approach is followed, based on the definition given by John Malcolm :

> ... visual language is a multi-dimensional phenomenon, based largely on semiotics and structuralism (Malcolm, p.22) [49].

The multi-dimensionality of a visual language lies upon the fact that a visual image can be experienced through the viewer's senses. Previous experience which is stored as memory allows such level of decoding. Visual signs can be interpreted into messages through the perceptual process in the same way speech can result in the form of a visual component through one's imagination. The speech also contains a visual aspect in the same way other means and signs contain words and messages.

Light can also be used to create a visual sign since the process of decoding a visual sign that does not contain text is faster and immediate [31]. Similar examples of light being used as a visual signal are the traffic lights and lighthouses. Traffic lights coordinate traffic and mobility in the urban space by altering the colour of the light. Lighthouses, indicate and warn the existence of dangerous coastlines. An example of the way light can act as a means of communication in interior spaces is the projection of arrows on the floor in IKEA stores, that act as a form of orientation in the space [87].

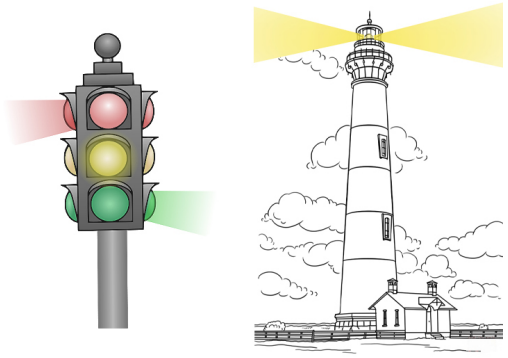

Figure 3.1: Traffic lights and lighthouses are forms of visual signs where light is being used..

Moving on to the way visual language is handled in this study, it needs to be highlighted that the combination of visual and verbal ways for learning has been of use for the past two decades [73]. The reason is that visual literacy enhances students' memory since it is an active learning approach. In this case, though, the aspect of visual language focuses on the enhancement of existing spatial signs by using light, that indicates the change of activities during the daily schedule. The light can act as a signal, communicating to the users, which in this case are the students, the various activities.

3.3 Storytelling

Storytelling is the art of narration and is widely known from literature and the movie industry. Stories have survived through the years, and the art of storytelling has become a fundamental part of design processes as it is considered to be one of the most efficient communication tools. The principles of storytelling are content, execution and interaction. In terms of content, the story needs to have a logical progression, that will have clear transition periods (execution). Interaction, as the word implies, underlines the importance of communication between the creator and the user [67].

The art of storytelling also holds a significant role in education, especially since it has been proved that narration supports memory development but also enhances abilities such us linking events, providing information and elaborating [36][57]. Digital storytelling is a form of communication that allows everyone to narrate their own story using interfaces and software while at the same time, acts as a tool for the educators [78][58].

Since storytelling already exists in one form in educational spaces, lighting can be used to enhance another aspect of it. In this case, there will be a parallelism between the traditional way of narrating through speech and the visual narration, which will be described in the following figure.

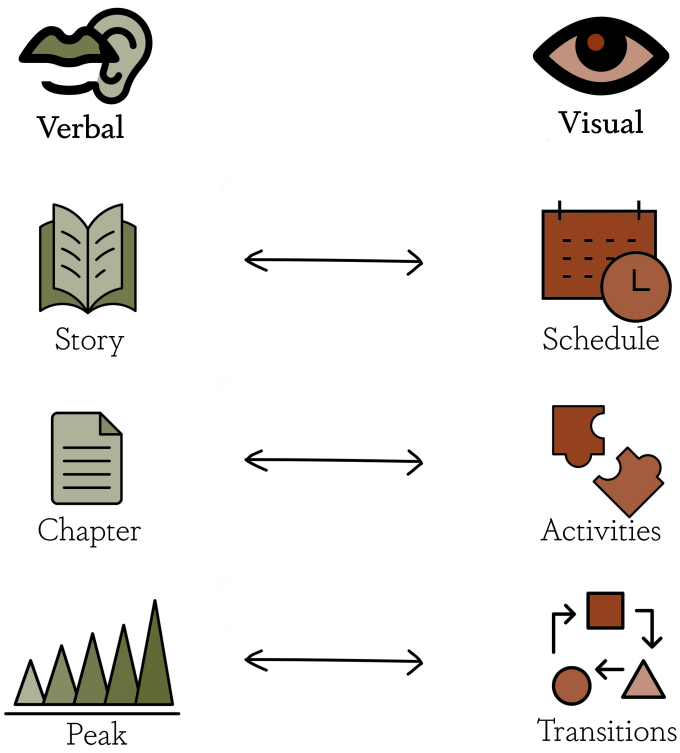

Figure 3.2: Illustration revealing the use of narration as a visual process.

In this illustration, one can see in the left part, the way a story is narrated. Storytelling is a verbal process where speech and hearing are used. A story is a set of chapters that are tied together through the peaks they contain. These peaks are the elements which tie together the story. The story's coherence depends on its core and the rhythm of narration. During this thesis, the notions of story, chapter and peaks are mapped to different concepts. The narration process is not verbal but visual in this case and based upon the principles of visual languages. The story which needs to be narrated is the daily schedule of the school. This schedule consists of different activities (chapters) throughout the day. These activities are interconnected through the transition periods (peaks), which reveal the alteration of actions. These components are the core around which further investigation will be performed, regarding the necessity of schedule and its enhancement.

3.4 Rhythms and routines

Routines are defined as sets of activities which follow a repetitive pattern during the day. People are familiar with natural patterns and tend to create routines based on those patterns. The sequence of light and darkness is the most important cycle of the day. Human existence depends on these cycles of light. Almost every human activity develops following these light alternations. Education, mobility and work are primarily taking part during the light hours, and it has only been during the past years that the use of electric light has allowed the extent of light hours. The link between human evolution and development with day and night has its roots mainly in the fact that light also regulates the internal biological clocks and rhythms of all creatures [24]. Specifically, in mammals, the master clock is regulated by the suprachiasmatic nuclei (SCN). A circadian rhythm is a form of interaction between the human body and the environment. In humans, the circadian rhythm is linked to sleep patterns and the secretion of specific hormones such as melatonin and serotonin [6]. In case this interaction is disrupted; there are side effects that are primarily connected to sleep disorders [35].

3.4.1 Importance of routines in child development

Natural rhythms are essential, and their consistency is valuable since they regulate humans' biological clocks. Humans' internal rhythms are entrained to the patterns of light and darkness; in the same way, everyday activities are developed according to the same patterns. If the natural rhythms are thought to be of a broader scale, then the daily routines are a scaled-down version of them. Part of these routines is scheduled and followed in educational systems. Schedules of daily activities are repeated in classrooms in a precise way.

The existence of a schedule is essential in children's development, especially for preschool kids. Routines in kindergartens are described as simple steps and tasks that

take place during the day. They provide though, consistency, confidence, security and trust [66]. The first indicator of daily patterns for children is nap routines. Bedtime routines are associated with children's well being and development. Bedtime quality affects daytime activities and bears an impact on the learning process. High sleep quality enhances a healthy attitude towards learning and is also vital for dental health, especially for toddlers [38]. The biorhythms which are responsible for the sleep-wake patterns are the circadian and ultradian rhythm. Those two rhythms undergo rapid changes during the first two years of age. The stabilisation of the circadian rhythm occurs when sleep patterns are kept consistent during that period. Lack of consistency may result in sleep disturbances since infants and toddlers are more sensitive to the destabilisation of their sleep [74].

Nap routines are also an essential part of the daily schedule in kindergartens. Scheduled activities in preschool are essential for creating a safe and stable environment and help children overcome the stress and anxiety of finding themselves in a new environment [93]. Routines enhance time perception and support the learning process through the creation of a framework within which children can perform and interact [94]. The necessity of patterns in everyday life is apparent and exists in higher education as well. Schedules are consistent in terms of activities throughout primary, secondary and high school. The regulators of those schedules are the educators who ensure the adherence to the schedule. The following proposal introduces an additional parameter which focuses on the way the daily routines can be supported by the space itself using dynamic elements such as light.

Chapter 4

Problem statement

The background research led in the definition of the research question presented as follows. The investigation of the research question is the core of this study. The research question aims in revealing a different aspect of the light, focusing primarily on the interaction between the light and the user. The formation of the research question is set as follows:

> How can **light** act as a means of **dialogue** between educational spaces and **children**?

The objective is the creation of an extra light layer which will have different functionality. The purpose of this lighting will result in triggering a response in terms of activity or movement on behalf of the children. Additionally, this will result in forming transition periods between the different activities during the day. The lighting will act as a tool for signifying the transition between the activities based on one of the leading biological needs light holds, which is time orientation in space. Time orientation is used as a principle, and the electric light will be used to cover this very need following the schedule of the day by signifying the different activities. The placement of this light layer in space will follow the children's scale. Therefore the height can vary based on the age group. The perception of space as well as the visual development during childhood is essential for the lighting proposal. For the evaluation of a possible solution, the children's point of view needs to be investigated.

4.1 Success criteria

The research question and background research, as mentioned above, resulted in pointing out the success criteria which are used as an assessment tool for the final lighting proposal.

The criteria are set as follows :

- Use of different lighting by enhancing different **elements of the space.**
- Focus on **changes of brightness** and movement performed in a subtle way.
- Design a lighting scenario which will be mainly perceived by the **peripheral vision**.
- The lighting standards are not to be met by the mere use of this light layer but **combined with** the functional/task layer.

Chapter 5

Analysis

This chapter analyses the primary topics related to the research question. The knowledge and main topics deriving from this investigation will be used in the methodology leading to the design proposal. The decomposing of the research question led to four main fields of inquiry which are presented in the figure below.

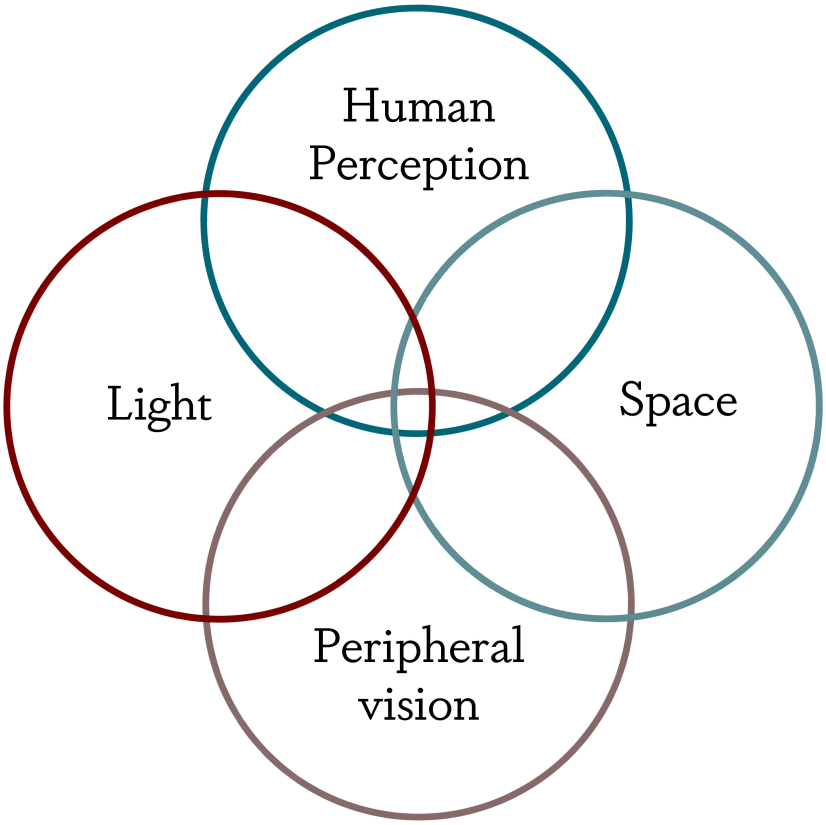

Figure 5.1: The main topics of investigation.

The four topics will be analysed separately, although they are interconnected and should all be taken into account in terms of design. The subjects are light, human perception, space and peripheral vision. The notions of light and space are directly mentioned in the research question, as for perception, and peripheral vision they are two of the tools defining the way light and space are experienced. Since the focus of this study is children's spaces, those tools need further investigation as there are fundamental differences in the way children and adults, experience and use space.

5.1 Light

Light is the first topic of investigation and is divided into three subsections expressing the necessity of natural light as a biological need and moving on to the way light affects interior space. The aim is the use of the basic principles that light carries, relating it to the human's biology and interior spaces, creating a link with the exterior environment.

Firstly the basic biological needs related to light will be presented emphasising the need for time orientation in space. Furthermore, the aspect of light in space as a tool for creating atmospheres will be stated, and the way light can act as a symbol in space needs to be investigated.

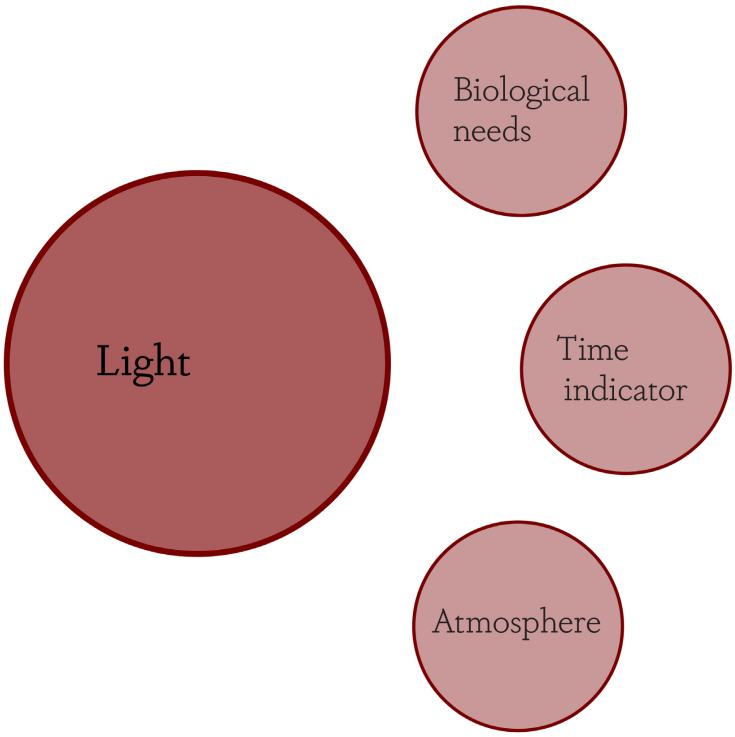

Figure 5.2: Subsections of the light topic.

5.1.1 Biological needs

Humans' familiarity with light derives from the fact of it being an inseparable part of everyday life. The word light is associated with sunlight and therefore natural light, even though, especially, at this time the essence and design of electric light are of utmost importance. The necessity of light in terms of biological needs but also health is apparent due to research programs which have proved that light acts as a primary regulator of circadian rhythms. Circadian rhythms are defined as daily patterns of body temperature, sleeping and wake cycles as well as hormone regulation and production, synchronised with light and following the 24-hour cycle of the day [84]. They are apparent in all animals and plants as well as humans. The regulation of these cycles, along with the necessary precautions for preventing their disruption belong to the health domain [8].

Light also covers biological needs linked primarily to orientation, space and stimulation. The basic biological needs as presented by William Lam in his book *"Perception and lighting as form givers for architecture"* are linked to the notions of location, time, weather enclosure, territory, relaxation and place [43]. The existence of light allows the recognition of the surrounding area and therefore, the extraction of the necessary amount of information regarding space's boundaries and location. This knowledge allows the user to be able to move around an area, establishing a sense of security. Light is also an indicator of weather. The direct sunlight is a sign of good weather, while the existence of dim ambient light is the result of a cloudy or overcast day. Natural light even during stable weather conditions, undergoes vast variations in terms of intensity which are not always perceivable by the human eye. The changes of natural light apart from the different weather conditions, follow the cycle of the day, revealing a pattern of light and darkness. The alterations in light are also a time indicator. The orange and pink light that is visible near the horizon is a sign of either sunrise or sunset. The result of this need for time orientation is the conservation of balance between day and night [43].

5.1.2 Light as a time indicator

Following up on the basic biological needs related to light, the focus of this study is the need for time orientation. It has already been stated that light changes throughout the day can indicate the time or part of the day, and the same principle can be applied in interior spaces as well. Contact with natural light throughout the day is essential and nowadays the design of openings providing view and contact with the exterior environment, while acting as a medium for the daylight to enter the space, has been on the spotlight [51].

Time orientation in exterior environments is linked to the changes and variations of daylight, while time orientation in interior spaces consists of multiple parameters. The first one is the existence of daylight in the interior space, which acts as a link between inner and outer space. The second parameter is related to electrical light. The electrical light can also act as an indicator of time following the changes and rhythm of activities

that take place in interior space, by changing one or more of its principles (luminance, illuminance, colour, temperature, direction or distribution) [15]. The last parameter derives from the combination of the previous ones. For providing time orientation, the essence of time in the interior needs to be consistent with the exterior environment. This aspect is also linked to the user's expectations regarding the contrast between the interior and exterior spaces. For instance, during the daytime, it is expected that the exterior area needs to be brighter due to daylight, while after sunset, the interior spaces are expected to be brighter compared to the exterior [43].

5.1.3 Atmosphere and light

The atmosphere is an intangible element that can be communicated by experience and in terms of emotional response. The notion of the atmosphere is linked to architecture and built space in this study. The atmosphere is the mental image of a space each person creates after visiting it. Even though in many cases, atmosphere perception is associated with vision, it is a multi-sensory process, where all five senses are incorporated. As Juhani Pallasmaa mentions:

> *"Atmosphere is similarly an exchange between material or existent properties of the place and the immaterial realm of human perception and imagination. (Pallasmaa, p.232)"* [60]

Atmospheric perception is grasped and sensed before one has managed to analyse the details and aspects of the space since it happens subconsciously. The elements responsible for defining and shaping an atmosphere are numerous, but the current analysis focuses on the element of light. According to Böhme, light cannot be seen, but what one can evaluate is part of the results created by light. In interior spaces, light can create contrasts and shadows, it can enhance shapes and forms which already exist in space, but light itself is not visible [10]. It can be experienced though, and expressed in a phenomenological way, by the creation of atmosphere. Lighting can be a useful tool for enhancing and revealing parts of the existing architecture but also as a means for establishing its aesthetic aspect [86]. Apart from the biological needs presented above, the users' psychological needs need to be expressed and therefore resolved. Those needs are the motivation for creating atmospheres through architecture and design. The various requirements and activities can be expressed through multiple light settings and therefore, adaptive atmospheres [25]. Light can affect the mood and emotional response of the user towards space but also affect the activity that takes place in it, making it an essential part of atmosphere perception [19]. The use of dynamic light can result in atmospheres that provoke different impressions regarding the same space, such as lively, cosy or office-like. Warm light has an impact on the way space is perceived, but also on its evaluation by usually resulting in the creation of a cosy and warm environment as opposed to cold lighting [89][39]. The perceived atmosphere of a space is a crucial

element even though it cannot be seen in terms of vision. Therefore it holds an essential role in terms of felt space and experience, especially when multiple activities take place in a single space.

5.2 Human perception

Human perception is a complex process aiming in recognition of one's surroundings. According to Abbasov's book "Psychology of visual perception," it is a form of knowledge of reality:

> *"Perception is the systematization, interpretation of information coming from the senses. (Abbasov, 2019, p.6)"* [1]

Perception, as described by Abbasov, is also related to time and space, bearing the aspects of constancy, structure and selectivity. Even though perception is usually linked to vision, it is the outcome of the coexistence and cooperation of all five senses. Additionally, based on William Lam, it consists of three different stages, highlighting the importance of memories as a form of existing knowledge [43]. The three stages are combined and apply previous perceptual data in the form of expectations when experiencing space for the first time.

> *" ... our very sense that there is a world is itself a phenomenon of perception. (Jacobson, 2017, p.5)"* [37]

Perception is a multisensory process evolving throughout one's life. Research has revealed that perception develops since childhood, evolving and advancing through the years. [55]. It is a fundamental process through one's life assisting in apprehending, combining and storing knowledge and experience.

Advancing in the analysis process human perception is decomposed into three separate subsections as depicted in the following figure. Initially, the element of human scale is going to be investigated, pointing out the main differences of the perceptual process between children and adults. Additionally, the domain of cognition is investigated, revealing its relation to perception, and finally, the basic principles and guidelines of colour theory and its use in space are pointed out. The goal is to highlight the elements which are going to be used further in the process.

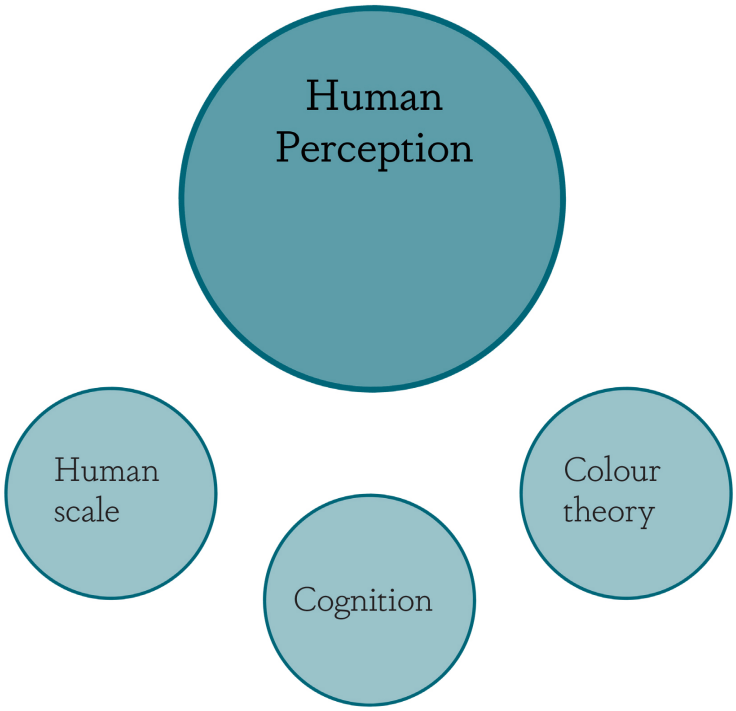

Figure 5.3: Subsections of the human perception topic.

5.2.1 Human scale and perception

Human scale is a crucial element when describing and referring to the perceptual process. The primary and most important reference for apprehending and "decoding" one's surrounding is their scale. Humans tend to use as references things that are familiar to them. People experiencing space for the first time, use, subconsciously, two essential elements, their scale and previous knowledge or memory regarding spaces and areas looking similar to the existing one. The human scale has been a reference point in design for years, even though there is a revived interest in its use and influence on the design process, especially in terms of user-based design [22]. From a purely practical point of view, human-scale defines the amount of included information in the visual field of a viewer. An example of the differences based on human-scale is presented in the following illustration. In the first row of sketches, the room is the same in terms of dimensions, and the investigated variable depends on the viewer's height. The first case is an adult of 1.70m height while in the second case, the viewer is a child of 0.70m height. The green and red colour replicate the visual field accordingly in both cases. The change in scale also results in the amount of information on the field of view for each case. An adult's visual field is split almost equally between information placed closer to the ceiling and floor while for a child, their field of view allows them to focus on the details placed closer to the floor.

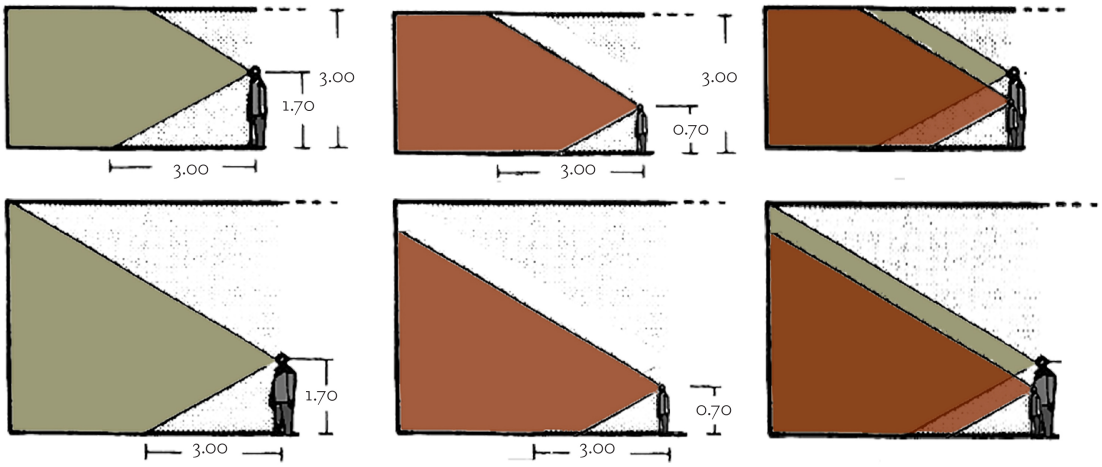

Figure 5.4: Sketches are illustrating how the difference in scale affects the perceived details of scale, found in the visual field. *(Initial sketch can be found in p.25 of the book "Architect's data" by Ernst and Peter Neufert [56].)*

The second row of sketches highlights this difference of visible details, while the overall height of the room is above 3.00m, which is the most common height for rooms nowadays. Focusing on the last sketches, one can see the differences in the visual fields. The reason the fields of vision are different is a matter of the eyes' placement; therefore, a matter of the overall person's scale.

5.2.2 Cognition

Perception and cognition are thought to be two indistinguishable actions, even though both of them take part in the deciphering procedure of the surrounding environment and the activities that take place in it. Perception has been characterised as an automated and unconscious process, in comparison to cognition which is thought to be a controlled and intentional process [85]. The automation of perception is linked to the involuntary use of the five senses as a fundamental tool for understanding one's surroundings[80].

Cognition involves reasoning, problem-solving, along with knowledge and memory. In terms of knowledge, cognition is related to the learning process, since the amount of information stored in the conscious part of our brain is gained knowledge, further used during the perceptual process [64] [79]. There are several theories regarding the link and frequent merge of these processes. The majority of these theories is linked to different stages of human development. Both perception and cognition evolve following the advancement of years, and in particular moments one of the two processes is responsible for one's understanding and learning. This development also acts as a tool for understanding the philosophical advancement of the human species [53]. It has already been stated that in terms of perception, the visual element is the most dominant one, and

researchers divide its development into three stages, early, intermediate and late vision. During the early stage of vision, the senses are responsible for perceiving and decoding the surrounding elements. During the intermediate stage, object identification and representation is based on memories and stored in the long-term memory. In the late stage, perception is mainly based on acquired knowledge, concluding in the importance of cognition at this point [80].

5.2.3 Colour theory

Colour is a fundamental element of the perceptual process, contributing to shape discrimination and boundary clarification. From a scientific point of view, colour is merely the perceived representation of light wavelengths which intrigue different photoreceptors of the eye [2]. Based on Joseph Albers's book "Intersecting colours: Josef Albers and his contemporaries" he states:

> *"Color, in my opinion, behaves like a man in two distinct ways: first in self-realization and then in the realizations of relationships with others..." (Albers, 2015, p.85) [2]*

Albers supported that colour perception is relative since it depends on the surrounding area, and the elements composing it. Colours can be perceived differently based on the contrast but are also affected by the background colour. One of Albers experiments focused on the difference in perception based on the background colour leading to combinations which created an altered perception of the same colours.

In terms of design and spatial composition, colour is considered an environmental factor apart from a design element. There are three different environmental factors as described by Baker, which are the ambient, design and social factors. Colour is categorised as a design factor along with architecture, materials and spatial layout, as for lighting is under the ambient factors along with music, scent and temperature [3]. These factors have a significant impact regarding the function and emotional response they provoke to the user, and the colour is one of the vital elements of three-dimensional space. The use of a specific colour is thought of having various effects on the viewer, as each colour bears different characteristics and qualities. For instance, blue and green are soothing and calm while yellow is related to warmth and awareness, and red is associated with stimulation and alert [61]. These qualities are taken into consideration when colour is used in space while following and supporting at the same time, the functional needs of the space.

The range of colours which can be perceived by the human eye is limited to the visible spectrum of light. Apart from perception, colour is also a matter of preference and therefore depends on gender, cultural, and age differences along with educational background [27] [9]. Research has revealed that colour preference differs in early and later age stages. Since the present study investigates matters related to educational spaces and children, this is also the focus regarding colour. First of all, in terms of preference,

younger children seem to prefer brighter and more vivid colours compared to college students and adults [96] [27]. Kindergarten children have a preference towards warm colours, with a higher tendency to red that seems to decline during the first grades of primary school [26]. Blue hues are almost equally preferred among students, especially during higher grades. Apart from age, gender is also a factor of differentiation regarding colour perception and preference, especially for blue, green, pink and black, while the change in preference of yellow colour is the most noticeable in the different ages [52].

The spatial parameter of colour is essential, especially in educational spaces, since it affects the mood and students' performance. Tregenza presents some general factors affecting colour perception and recognition in space in the book *The design of lighting*. Colour depends on the brightness of the surrounding area and the size of the surface it covers. The wider the surface, the higher the perceived saturation. Additionally, the amount of time this colour is in the field of view is essential, as the permanence of the colour affects the way it appears [84]. The purpose and function of the space also define the use of colour. For instance, in an art classroom, more vivid colours are chosen due to the activity taking place in the classroom but also since it is a space used for a certain amount of time during the week [83]. The factors mentioned above synthesise and highlight the importance of colour as a three-dimensional element in space, used for creating spatial and dimensional relationships while affecting the psychological aspect on behalf of the viewer [96].

5.3 Space

Space can be defined as the enclosure of dimensional elements, brought together in an attempt of creating an element which will potentially inhabit human activity. Space is produced based on human needs, mobility and potential hosted activities. Following the figure below, there are three subtopics related to space. These are spatial cognition, ambience and communication through space. This topic's focus is the perspective and point of view on behalf of the children since the area of interest is related to educational spaces. Therefore, the investigation is led by spatial cognition and the first steps of spatial development in children. Ambience focuses on the element of light and its effect of spatial perception. Communication through space is a subtopic focusing on the information extracted from each spatial element. The results of this investigation conclude in the main aspects of space used further on in the process, both as elements of analysis and design.

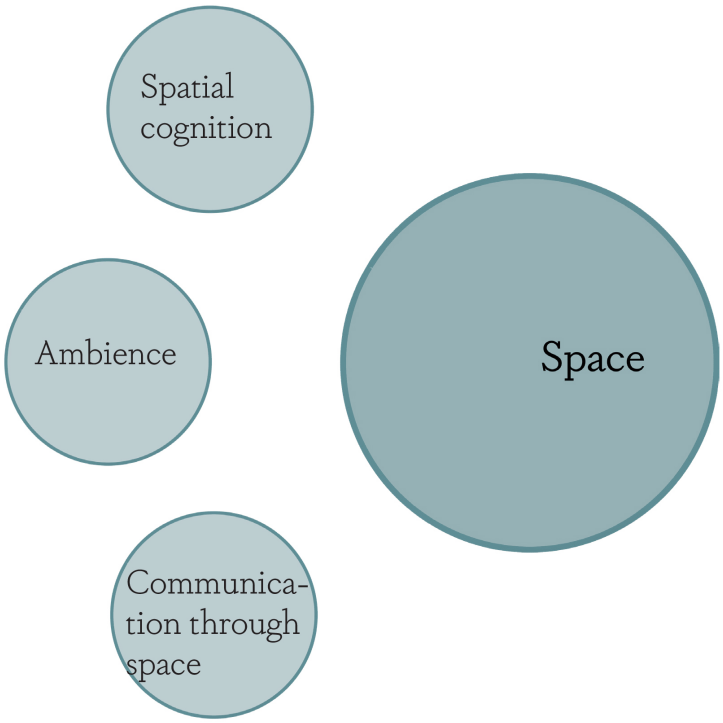

Figure 5.5: Subsections of the space topic.

5.3.1 Spatial cognition

Spatial cognition is a multisensory process which requires the co-operation of all senses. Spatial intelligence evolves through the years and is adaptive based on the surrounding in which each one develops. Spatial thinking contributes to further understanding of daily relations between notions such as the social and organisational system. Spatial cognition is a milestone of intellectual growth since it is related to various everyday performances [88]. The notion and importance of space have been a matter of debate for many years. The cause of this debate is its definition both as objective and subjective. The "objective" space is related to its physical aspect, while "subjective" space is more intuitive and linked to an empirical and intimate investigation [82].

Spatial cognition is fundamental for navigation and orientation, both for children and adults. The notions of navigation and orientation are not strictly linked to a large-scale area, like a neighbourhood or a city. During the early stages of development, they are related to line and angle appreciation along with size recognition and relative size of objects. The process of spatial development undergoes for many years. The majority of sensory and cognitive functions undergo extensive developmental changes from childhood until adulthood. Maturity and experience acquirement are essential elements of cognition growth. Previous experience is essential both for spatial navigation

and orientation. Even though spatial information is primarily gathered through vision, various researches have revealed that haptic perception is the dominant perceptual sense for children, due to the belief that is fully developed at an early age [63] [59].

The primary elements perceived and processed in terms of spatial cognition by children are shapes and lines, followed by distance and directions. Shapes and lines are also the main elements in children's' drawings. Children's illustrations enhance cognition and are a way to express how they perceive their surroundings, but it can also be an indicator, during early ages, of developmental difficulties [14]. The reason these elements are predominant is that it is easier to analyse an unknown space in terms of geometry and shapes at a glance and further pay attention to the details. Children have an egocentric (viewer-dependent) way of analysing spatial information [82]. The egocentric way of spatial analysis is linked to the element of scale, both in terms of human scale but also spatial scale [5]. Piaget describes this process as part of the development stages. The first stage (sensorimotor stage) that lasts two years is based on haptic perception. The second stage (Preoperational stage) is egocentric, and only during the third stage (Concrete operational), the child starts taking into account other's thoughts and feeling, meaning that the perceived space is no longer their immediate surrounding environment but also incorporates others. During the fourth stage (Formal operational stage) the child begins to think about moral, philosophical and social issues [63].

Throughout the process of spatial cognition, children mainly rely on landmarks for wayfinding and navigation. Research has revealed that in terms of navigation and memory, young children relate easier to landmarks and junction points. It is stated though that it is easier for ten-year-old children to mentally relate certain elements to landmarks compared to six and eight-year-old children [47].

Cognitional development is essential for children, especially since it is a progressive process that is not fully formed during childhood. In the course of this process apart from vision, haptic perception is predominant during the first years of age. Moreover, shape, line and angle appreciation are among the primary elements forming the notion of spatial perception in children.

5.3.2 Ambience

Perception of the ambience atmosphere is based and affected by previous experience. The ambience of space consists of various elements, but the focus lies primarily upon light. The difference of ambience is its relation to space, and hence its perception as a unifying element [68]. There are various ways of communication between a space and its users. This achievement is possible through the use of physical means, which are spatial elements used as symbols, but it can also be achieved through intangible elements perceived by sensations, like spatial ambience [30]. As Peter Tregenza states:

> *Patterns of light and colour act as clues to the nature of the room by triggering associations with places experienced in the past. (Tregenza,1998, p.88)* [84]

These associations can be expressed and perceived in various ways based on the experience each user has. There is not a universal language regarding ambience in space and related experience; therefore, a space used daily tends to become a reference for another interior that shares similar use. Reference spaces are part of what is stated as memories or previous experiences. The ambience of space follows its use but also the expectations of its users. Hence sensed ambience of an office and a club cannot be the same and are not expected to be the same. The ambience is both linked to previous experience but also expectations, and focuses on the emotional response the user has towards space.

5.3.3 Communication through space

Space is a composition of different elements having various functional qualities. The elements of space can be highlighted using various design factors such as colour, material, texture or even light. The reason a specific element needs to be dominant in space is due to its importance in terms of space functionality or because it represents and conveys a vital message [97]. In some cases, there are certain spatial elements or characteristics which contribute to space's identity. Therefore these elements are essential and emphasising them contributes to the creation of a mental image that will be interwoven with the space in the viewer's memory.

There are also cases, in which specific elements bear a single meaning such us the exit symbols above doors that are used in cases of evacuation. The way spatial elements are treated in terms of significance is the result of visual management in space [32]. Openings in buildings, such as doors or windows, are a symbol of the connection between interior and exterior space. Windows lead natural light in the space while providing a view towards the outside. The door is the element leading a person either inside or outside of a room, symbolising movement in space. In terms of communication through space, the way a single element is managed can lead to various conclusions about the message it conveys [77]. For instance, the use of a particular colour around the doors of a building may indicate that these doors lead to spaces with similar function. Correspondingly, the lighting of the walls that have windows may indicate something about the orientation of the room. Another aspect of spacial elements is their use in terms of navigation in space through the creation of landmarks, which are fundamentally used as navigational spots. The element of contrast, in this case, can enhance wayfinding. There are various examples, and the solutions depend on the building, room or area of interest and its function. The immediacy of a visual component is the reason someone would use spatial elements as forms of communication with the user.

5.4 Peripheral vision

Peripheral vision is part of humans' field of vision and as the word indicates, and consists of the farthest parts of the visual field. It evolves and alters through childhood until adulthood. With age, vision changes and among the visual changes, there is also a gradual loss of the peripheral vision, resulting in the decreased reflex time since peripheral vision is responsible for monitoring. Even though peripheral vision is one of the main topics of interest, a general discussion regarding vision will be presented as well. As described in the following illustration, there are five subsections related to the topic of peripheral vision. The first subsection is a description of what is defined as vision, followed by an explanation of the visual process. The second subtopic focuses on the differences between central and peripheral vision. Additionally, the relation of peripheral vision and cognition is explained with the last two subtopics being the eye movement in space and visual development that focuses primarily on children. The element of peripheral vision is essential for the understanding of space and the description of the perceptual process, especially since it is also affected by human scale.

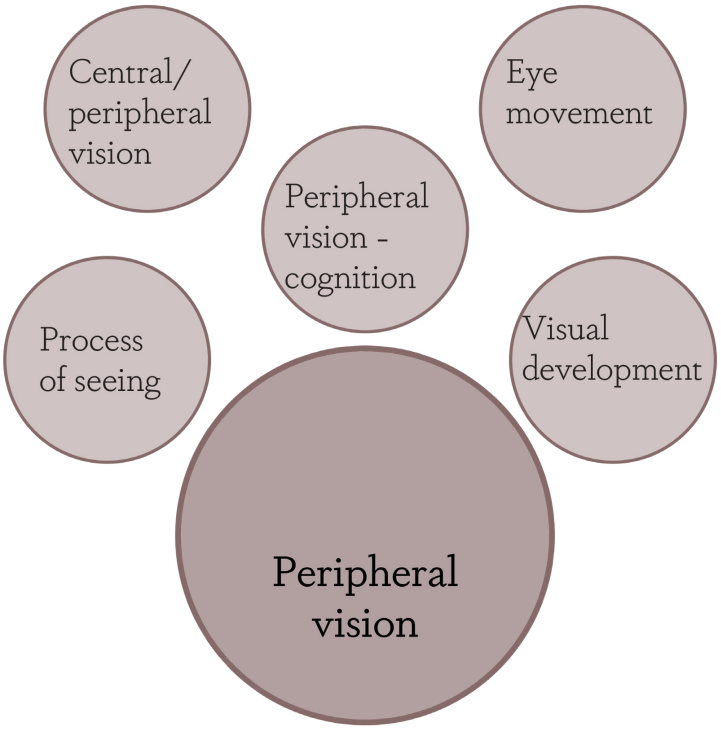

Figure 5.6: Subsections of the peripheral vision topic.

5.4.1 The process of seeing

The process of seeing is a complicated procedure whose achievement requires the co-operation of different organs. The eye is the primary source receiving information that are transferred to the human brain through the optic nerve. Humans' ability of vision depends on the existence of light. Light in space reveals the colours, shapes and details; therefore, the process of seeing is reliant to it. The visible spectrum for humans is between 400nm - 700nm, where around 400nm is purple colour and around 700nm is red [84].

The description of the visual process requires a brief explanation of the eye's anatomy. Reflected light from objects reaches the cornea, which is the front part of the eye through the iris focusing on the retina. The retina consists of photoreceptors, which are cells that react to light [72]. There are two types of photoreceptors in the retina linked with light, rods and cones. Rods are sensitive to lower light levels and do not provide information regarding colour. Cones function under high levels of light (daytime). Three types of cones are apparent in the retina, whose sensitivity varies based on the light's wavelengths. The combination of the three wavelength sensitivities results in colour perception. Photoreceptors connect the retina to the optic nerve, and the optic nerve carries the information to the visual cortex, which is located in the back of the brain [84]. The recognition and association of the visual stimulus with a notion is part of the brain functionality and is linked to acquired knowledge and memories.

5.4.2 Central and peripheral vision

Foveal and peripheral vision have many differences yet, at the same time, are codependent and complementary. Having only central vision would be as if being able to see through a narrow hole while being in a dark room. In case only peripheral vision was available, only a blurred image of the surroundings would be visible, without colour discrimination. It is also essential to highlight that due to binocular vision, each eye sees a slightly different image and its due to brain functions, the two images are perceived as one. The following illustration depicts the field of view each eye has.

The central field of view is no more than 2° degrees and is focused on a small area of the retina called fovea centralis [84]. Only these 2° degrees correspond to high visual acuity and the ability to detect small details. It is only 5° degrees from the centre that the clarity of vision is decreased in half and moving on further away from the centre vision blurs even more.

Peripheral vision is a relic of survival needs and therefore is primarily sensitive to movement and changes in brightness. Peripheral vision allows the constant monitoring of the ground. Peripheral sensitivity increases towards the edges of the visual field. Sudden changes in brightness are noticed faster when they occur closer to the edges of the visual field [29].

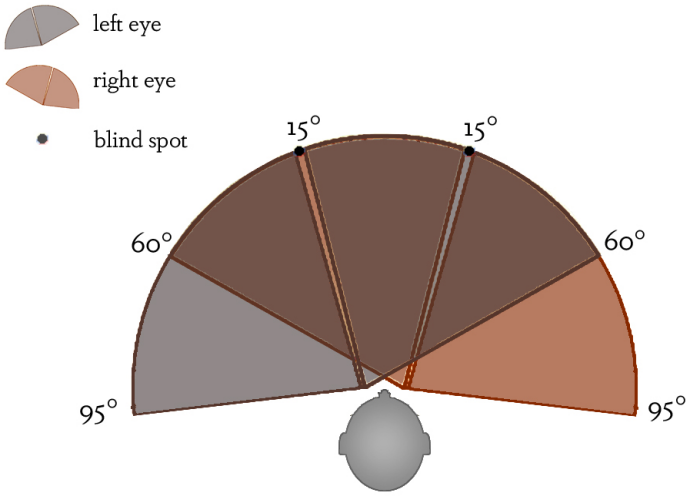

Figure 5.7: Visual field of left and right eye.

The forward-facing horizontal field of view is slightly over 210° degrees while the vertical field of vision is approximately 135° degrees [21]. In the forward-facing field of vision within 30° degrees symbol recognition is possible while the area of comfort is defined by a 60° degree visual range. Peripheral vision is considered to be from 60° to 110° degrees. Within this range a 35° degree for each side is the monocular peripheral field of view, meaning that this specific part is the peripheral visual field for each eye individually. From 95° to 110° degrees, is the part of far peripheral vision which, as stated above, has the highest sensitivity in brightness changes.

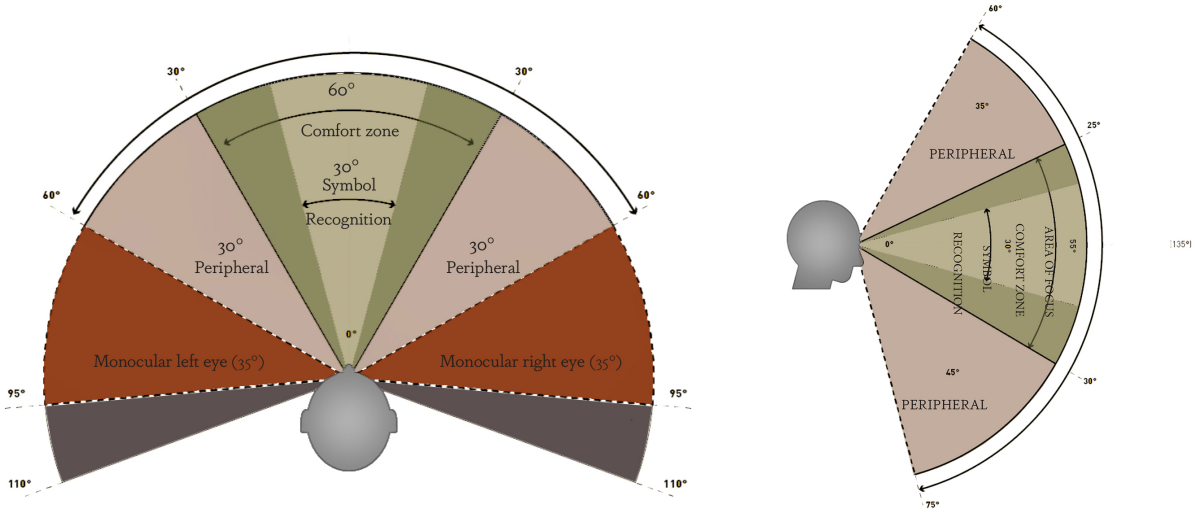

Figure 5.8: Central and peripheral view illustrations.

The vertical field of vision is also divided into central and peripheral vision. The central field of view, in this case is 55° degrees and this area includes symbol recognition and the comfort zone. The central part of the visual field is the focus area. The upper peripheral visual field is 35° degrees while the lower part is 45°. The lower part of peripheral vision is responsible for the monitoring of the ground.

Even though both central and peripheral vision are essential for perception, this thesis focuses mainly on the peripheral field of view and more specifically on its development regarding children. Visual development is a fundamental factor for perception and cognition.

Peripheral vision and cognition

Vision is frequently related to cognition and learning, especially regarding children. Even though during the first developmental stages, haptic perception is the dominant sense leading and regulating perception, vision is predominant during the transitional stages and is used by children to mimic new skills [54]. Peripheral vision is related to learning activities and reading skills [23]. Nevertheless, peripheral vision in children is different compared to adults, since its development continues until the age of twenty-two. The left part of the peripheral field of view tends to be slightly more advanced following the way children learn to write and read, from the left to the right [41] [91]. For written languages which follow the opposite direction, the right part of the peripheral vision is more sensitive.

Reading and writing are two of the most complex skills a child learns. The way a text is read requires the combination of central and peripheral view since the eyes move in a specific direction. The eye's movement results in the understanding and decoding of the given text. It is supported that in the same way written language is understood, symbols and signals are also perceived regarding peripheral vision [11].

5.4.3 Eye movement

Eye movement tracking has been used as a tool for various researches since it can reveal the way the eye explores and identifies the main elements of space [23]. Eye movements do not occur independently since the target is always the same for both eyes [8]. Studies regarding eye movements have revealed a link between the process of visual instruction and communication. The processes of reading and writing are linked to eye movements since their performance is not possible when having fixation points. Eye movement characteristics vary according to learning activities and difficulty. Hence fixation points also depend on the task, difficulty and age of the child. Eye movements or more specifically fixation point stimuli vary when comparing children and adults. Children tend to fixate more on negative stimuli while adults have extended fixation points for neutral or positive stimuli. Additionally, children cannot fixate on specific points for too long while for adults, it is easier to keep their eyes on a particular point for an extended period [23].

5.4.4 Visual development in children

Vision differs in infants, children and adults since it undergoes a developmental process that lasts till adulthood. From the moment the eyes begin to appear during the second week of pregnancy until adulthood, vision continually changes. Visual differences have an impact on perception and in the decoding process regarding one's surroundings.

From the moment a child is born, and for the first three years of life, the eyes and vision undergo rapid changes. Most babies are hyperoptic when born while astigmatism is common in infancy as well. Iris pigmentation occurs after birth, and the colour of the iris darkens during the first two years before acquiring its final colour [45]. Infants tend to perceive space as a fluid mass since they can only distinguish details of objects being close to them, and their surroundings are perceived as a blurred image [63]. Their attention mainly focuses on central view, as the expansion of their horizontal and vertical visual field evolves significantly during the first six months resulting in a field in terms of degrees closer to the one adults have [46] [28]. The focus on central vision is linked to the fact that spatial resolution is higher when the presented stimuli are part of the central vision and not in the peripheral visual field [12].

The progress of visual development is also apparent in preschool children and specifically regarding peripheral sensitivity which increases significantly from the age of three till the age of six. At the same time, visual acuity reaches its peak at the age of three [45]. During this time, visual development affects spatial perception, given that it is either perceived as "far space" or "near space". The peripheral field of view continues to expand and evolves until the age of twenty-two, meaning that up to that age, the peripheral field of view is more restricted compared to an adult. The changes, though, are not that intense compared to the first years of age. By the age of fifteen, peripheral sensitivity is similar to foveal sensitivity for static targets [42].

5.5 Design directions

The definition of the research question, along with the creation of success criteria, are used to create a frame within which the design evolves. The combination of these elements defines and highlights the main design directions of the project. Within these directions are the use of human scale in terms of light topology, aiming in the enhancement of spatial cognition by focusing at the same time on the peripheral view of the users.

Furthermore, the creation of a rhythmic pattern aims in the distinction of the various activities during the day. The change in brightness is of utmost importance since based on the analysis, there is increased sensitivity in the peripheral view. The colour temperature is going to be stable due to the focus on the peripheral vision, according to which the peripheral field of view is not sensitive to colour discrimination. The directions, as mentioned above, are enhanced and translated into a specific design framework.

Chapter 6

Design framework

The investigation of the four different topics resulted in gathering essential elements for the development of a design framework. This framework comes as a result of composing spatial elements, site (use case) analysis and light investigation, both in terms of existing electric light but also natural light and therefore proposing a set of tools and steps that act as guidelines for the analysis process. Through the presented illustration, the description of the proposed design framework is presented.

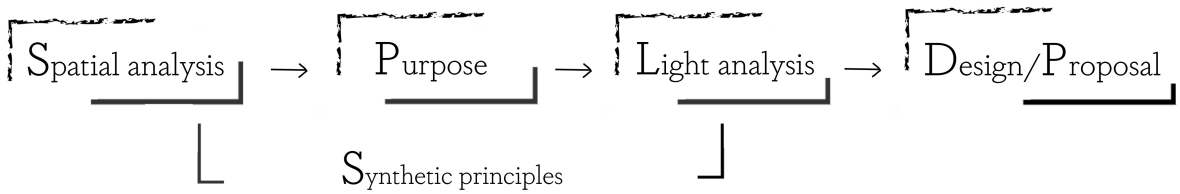

Figure 6.1: Illustration showing the steps composing the proposed design framework.

This framework constitutes a series of steps, primarily focusing on the spatial characteristics of the investigated space. Since architecture and design use elements as signs in the space, their investigation is fundamental [44]. The analysis of spatial signs establishes a profound understanding regarding space itself is essential for the design proposal. Furthermore, the purpose and specific use of the space needs to be stated along with potential problems that need to be resolved. This step is essential since it is the basis on which the design will evolve. The spatial and functional analysis lead in the investigation of light. This part begins with the description and illustration, if needed, of the existing lighting situation, both electric and natural light. Additionally, by combining the previous steps, the analysis is performed in terms of additional light layers in space[62]. At this point, it is necessary stating that there is a theoretical parameter, the synthetic principles, acting as common ground by synthesising and linking the spatial

and light analysis. The merge of these steps contributes to the design solution/proposal for the particular space.

The proposed design framework can be applied in any space, providing multiple design alternatives. Moreover, even though the steps can be the same, the resulting design proposal is based on the unique characteristics of each space. In that sense, the characteristics of each space which determine its identity are used for its enhancement. Considering that the identity of each space is unique, so are the elements composing it. Respectively, the elements and the approach used for resolving existing problems in space is also unique.

As illustrated below, the proposed workflow is the application of the design framework in a use case or multiple use cases and the proposal of multiple designs. The recommended steps are to be consistent for every case, and the variable is the functionality and spatial characteristics of each case determining the proposed design. What needs to be highlighted is that from a single-use case will emerge more than one solution in terms of design. The concept might be the same, but the application may be achieved in a variety of ways.

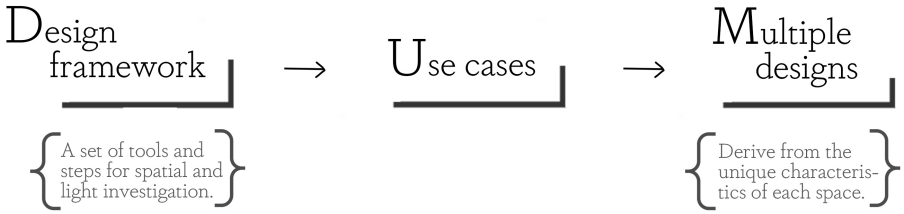

Figure 6.2: Illustration showing the way the framework can be applied resulting in multiple designs based on a use case.

The current project contains an example of the way this design framework can be applied and will be presented in the form of an investigation of a case study introduced in the following chapter.

6.1 Spatial analysis

> *"But form is conceived as an approximation as faithful as possible to the referred content, which remains unutterable." (Pellegrino, 2006, p.3) [62]*

The first set of steps concerns the spatial elements of the chosen space, focusing on their interpretation and understanding in terms of spatial semiotics [33]. Since architecture's primary goal is the creation of useful and functional space, the analysis of an existing space lies in the investigation of its compounds separately as presented in the illustration below.

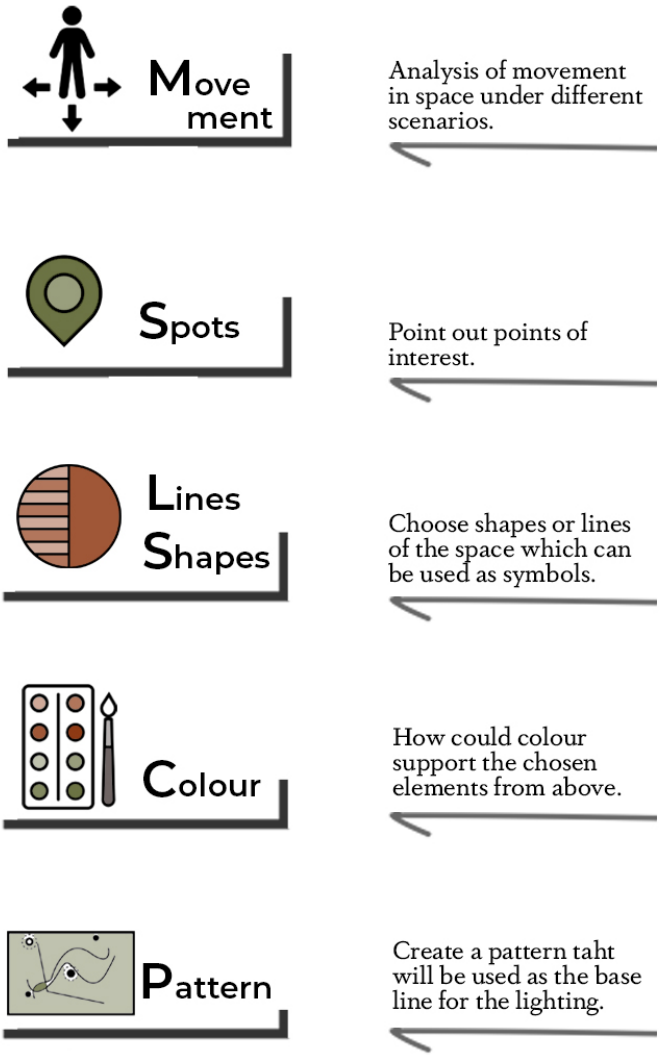

Figure 6.3: The steps of spatial analysis.

Firstly, a study of movement in space is conducted under various scenarios linked to the function of the space [25]. For instance, in case the area of interest is a train station, different movement studies need to be performed to reveal the way people move during rush hours and how the mobility changes under lower circulation. After the investigation of space's mobility, the main spots of interest are revealed, which are defined as the areas of space with a higher concentration in human mobility. Following the example used above these points of interest might be passages leading to the exterior space, a different platform, waiting areas or even purchase points. The third step is the investigation of the dominant shapes and lines appeared in the spots of interest. Those elements can potentially be used as signs or symbols in space by making them stand out. The

following step incorporates the use of colour in space. The geometry and colour analysis also reveals the balance of their composition, which is fundamental for the creation of a unified environment [65]. The final step of the spatial analysis incorporates the previous steps and aims in spotting the dominant elements of space to further use them for creating a basis for lighting [62].

6.2 Light analysis

The gathered data from the previous stage are the input for the light investigation. The first part is the description and evaluation of the existing lighting, in terms of natural light input, and lux levels regarding the electric light. For the needs of the current project, the proposal aims in the creation of an additional light layer; therefore, the standards are not part of the evaluation factors of the final proposal. The second step in the process is the definition of possible light placements based on the needs and scale of the space and its users.

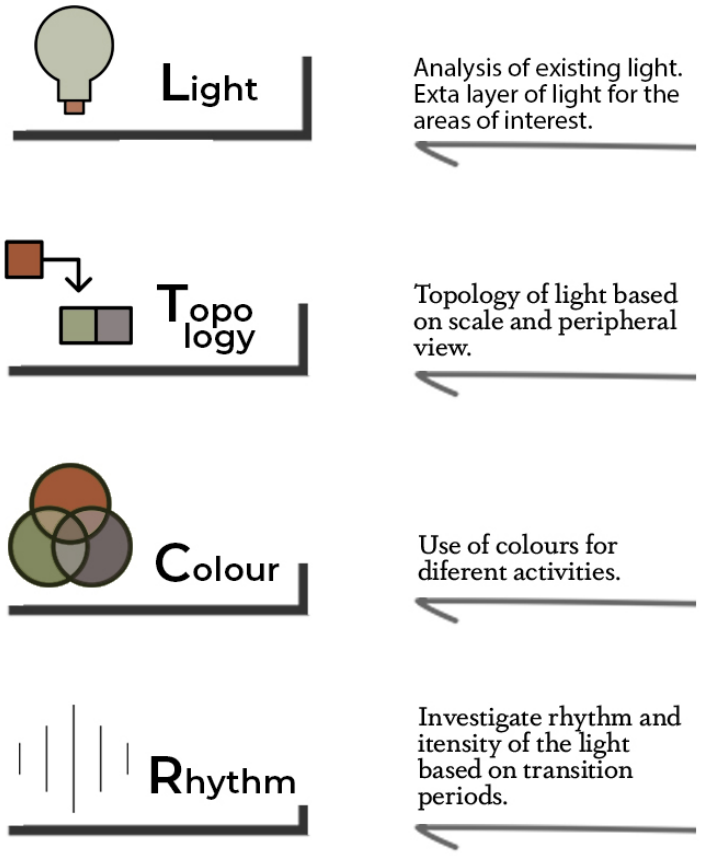

Figure 6.4: The steps of the light investigation.

The element of scale is essential in terms of light topology since perception is influenced both by spatial and human-scale [22]. Lights' placement needs to be followed by the analysis of the way light might enhance or define the different activities which take place in the space. The lighting scenarios should support the various functions of the space. Colour as a light variable can also be a factor indicating the change of spatial functionality or activity. The last part of the process is the investigation of rhythm. Rhythm can be used as an indicator of change and movement in the space [84]. The rhythm as a light variable can be expressed through brightness variations. Summing up, the steps described above contribute to the creation of a light-based design proposal.

6.3 Synthetic principles

> *"The ratio between rising and reposing, lightness and weight, independence and dependence, is at the very core of the human sense of what life is and ought to be, and as such it is a principal variable of style." (Arnheim, 1980, p.45)* [75]

As Arnheim states in his book *Art and Visual Perception*, the way our surroundings are perceived is holistic and unified. Visual perception in a glance is a unity of elements, textures, colours, lights and details [65]. The way space is synthesised and composed is based upon design principles. These principles are used as guidelines for the creation of a balanced and harmonious outcome. In the proposal of the guidelines mentioned above, the synthetic principles are the common ground for spatial and light analysis. These principles, which are widely used in the design process, are found both in the spatial and light analysis. The following illustration summarises the principles that will be further analysed. The present study focuses primarily on the elements of balance, rhythm, contrast and scale.

All six principles are codependent and interconnected even though in some cases seems to be treated independently. In reality, a proposed design solution, embodies all six principles, even though some of them are easier to distinguish even by users not related to design. The first one to be analysed is the principle of balance which is seemingly an intangible and abstract notion that cannot be translated into apparent spatial relationships. Balance is perceived and detected almost in an automated and occasionally subconscious way by the viewer without necessarily having a particular background related to design.

> *"We do not establish sizes, distances, directions, singly and then compare them piece by piece. Typically we see these characteristics as properties of the total visual field." (Arnheim, 1974, p.11)* [65]

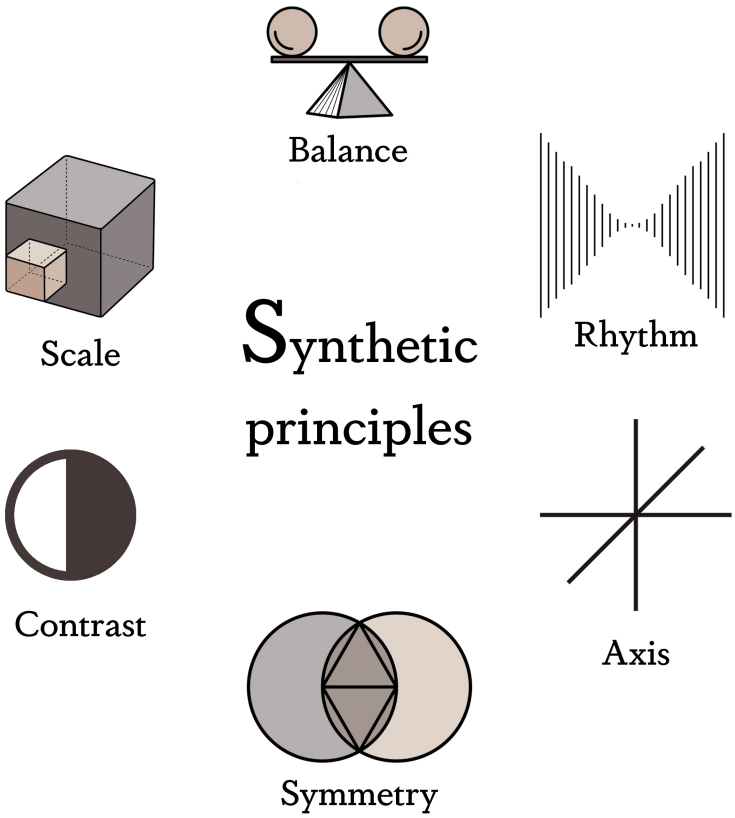

Figure 6.5: Synthetic principles are the common ground between spatial and light analysis.

As stated by Arnheim, balance is the perception of a composition as a unit and not separate elements. Design-wise, balance is primarily linked to the perceived weight of a synthesis. A spatial element that can be used as an example to investigate balance is a plain wall of a room. Anything placed in the lower part of the wall increases the "weight" of the bottom part leading the viewer to concentrate on it, so weight is influenced by location. Balance also depends on the size and spatial depth, since the relationship of an area and a single element affect perception [76]. Apart from size and location, colour can as well affect the balance of composition since bright colours seem "heavier" than dark ones [65]. The notions of size, placement and colour can be used as an expression of the second principle that is rhythm. Rhythm in space can be communicated through the repetition of the same element or group of elements. The success of its use lies in the analogy that can either be topological if the repetition is based on placement, dimensional in case the repetition follows the size of the element or related to saturation, hue and brightness in case of colour.

The next two principles are frequently used together. Using axis mainly aims in the division of space symmetrically or asymmetrically. An axis is fundamentally used as

a guideline for the design process. The principle of symmetry can be achieved in four ways. Through rotation, reflection, glide reflection and translational symmetry. The first two alternatives are more natural to distinguish compared to the last ones [16].

There is a variety of approaches to be used for achieving the principle of contrast. There can be a contrast in terms of brightness, saturation, intensity, size or shape. Contrast can be applied to highlight an element or attract attention to a specific area. An example of contrast is the application of bright and warm colours in staircases of public spaces for enhancing peoples' awareness [84]. The last principle is the element of scale. The definition of scale is the apparent relationship between spatial elements or the relationship between the space itself and the scale of the user. The design focuses on the human scale not only through the creation of objects following the science of anthropometry but also by creating spaces which respond to and follow the human scale.

Chapter 7

Case study

The current case study will act as an example of the design framework's application, described in the previous chapter. The chosen case study is a primary school situated in Athens, Greece. The following floorplan depicts the first floor of the school where the two classrooms of third and fourth grade are located. The classroom on the right is a fourth-grade classroom, and the one on the left is the third-grade classroom. The two classrooms were chosen due to their differences in orientation and layout in order to investigate two separate scenarios.

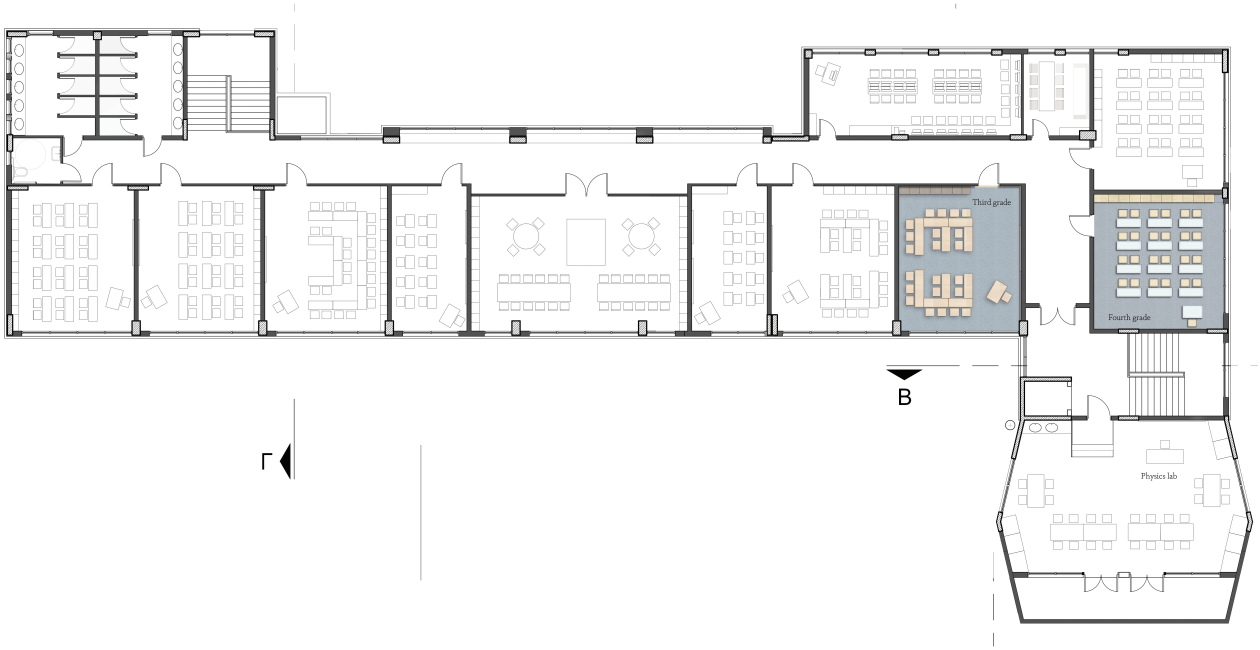

Figure 7.1: School floorplan. The coloured areas are the investigated classrooms.

In the following sections, the steps composing the design framework will be applied

and explained. During the analysis process, since each step will be presented for both classrooms in parallel, the third-grade classroom will be presented initially, followed by the fourth-grade classroom analysis.

7.1 Spatial analysis

The first part of the analysis is the spatial investigation. In the following subsections, the essential elements of space will be pointed out and analysed, leading to the composition of a spatial pattern as a final step.

7.1.1 Movement in space

Movement in space was investigated through the analysis of students' mobility. Since the collection of data in terms of spatial movement was not feasible, the analysis is based upon the students' hypothetical trajectories in the classroom. The investigation of movement under two different scenarios was analysed. The first one is the movement in the classroom during a course, and the second scenario is the movement in the classroom during break time. The nature of the course is not significant at this point and was not a variable for this step. In the following floor plans illustrating the third-grade classroom, the hypothetical movements linked to the layout of the desks in the classroom are visible, along with the paths' change under the two different scenarios.

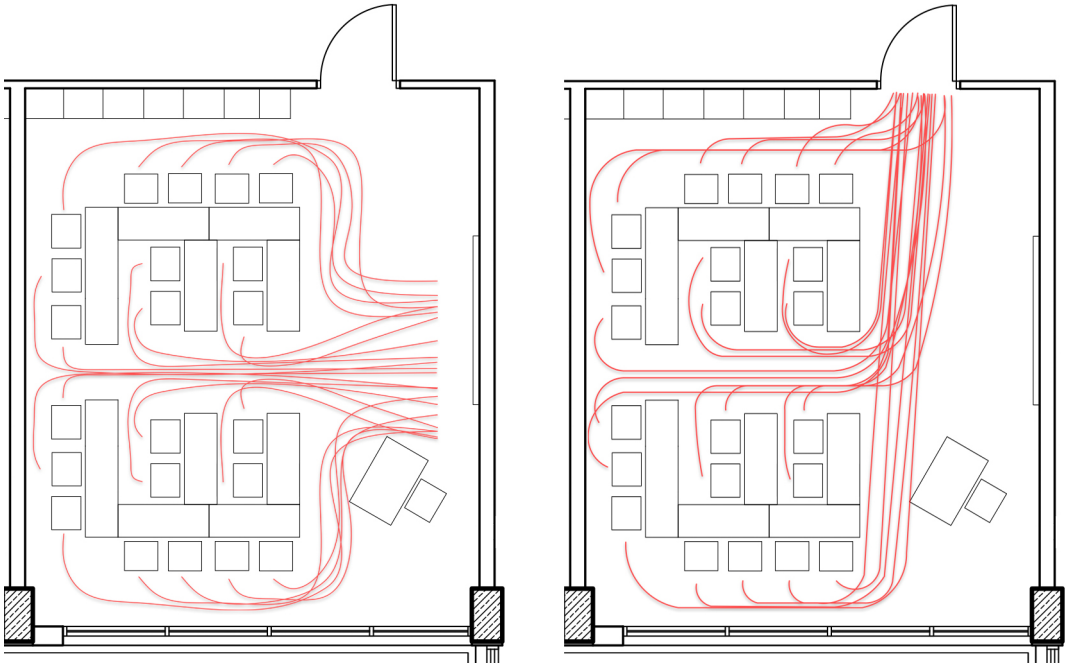

Figure 7.2: Floor plans illustrating the hypothetical trajectories of students (third-grade classroom).

The left floorplan illustrates the paths created during a course while in the second floorplan, the movement changes during the break time scenario. Based on the trajectories, a set of heat maps illustrating the different scenarios were produced. The colours in the heat maps represent the motion density in space. Red colours represent the areas with a higher concentration of trajectories, while areas of lower mobility are in blueish colours.

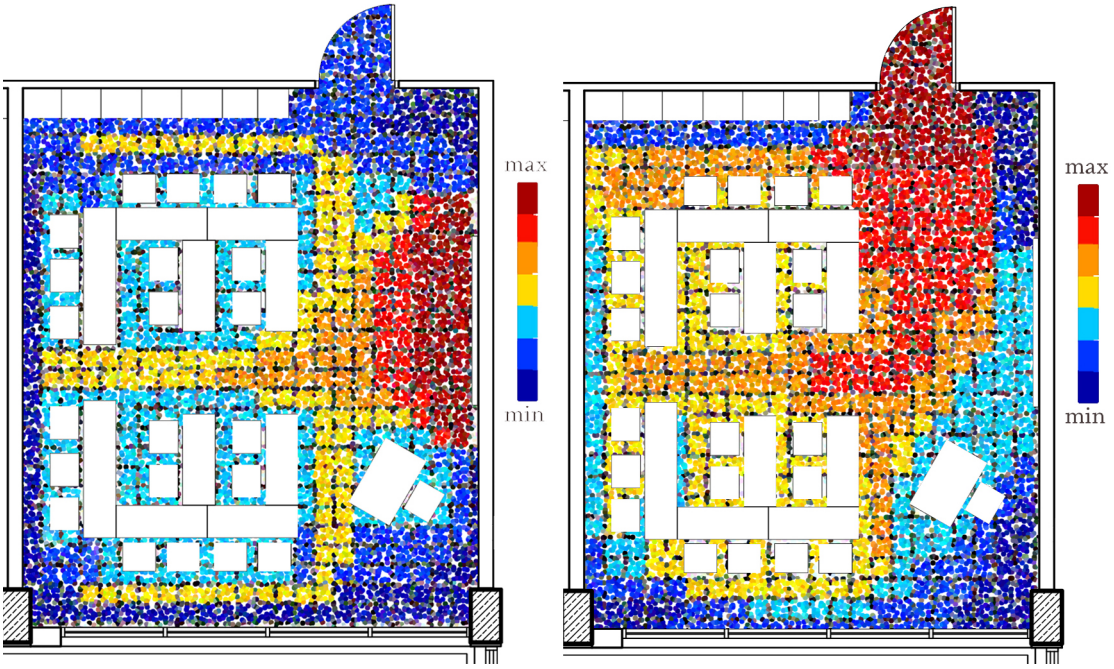

Figure 7.3: Heat maps illustrating the movement density in space (third-grade classroom).

The same process was followed for the analysis and illustration of the students' hypothetical trajectories in the fourth-grade classroom. The hypothesis concerning movement is based on the general layout of the classroom and the elements found in it. The primary difference between the two classrooms is the layout of the desks and therefore, the difference of possible movements under the two scenarios.

The following floor plans illustrate the possible paths of students under different scenarios. The left floorplan demonstrates the motion during a course, while the right plan represents the possible movement at break time. As seen in the previous classroom, both cases share some characteristics in terms of movement since the density of paths are similar closer to the board and the door, respectively.

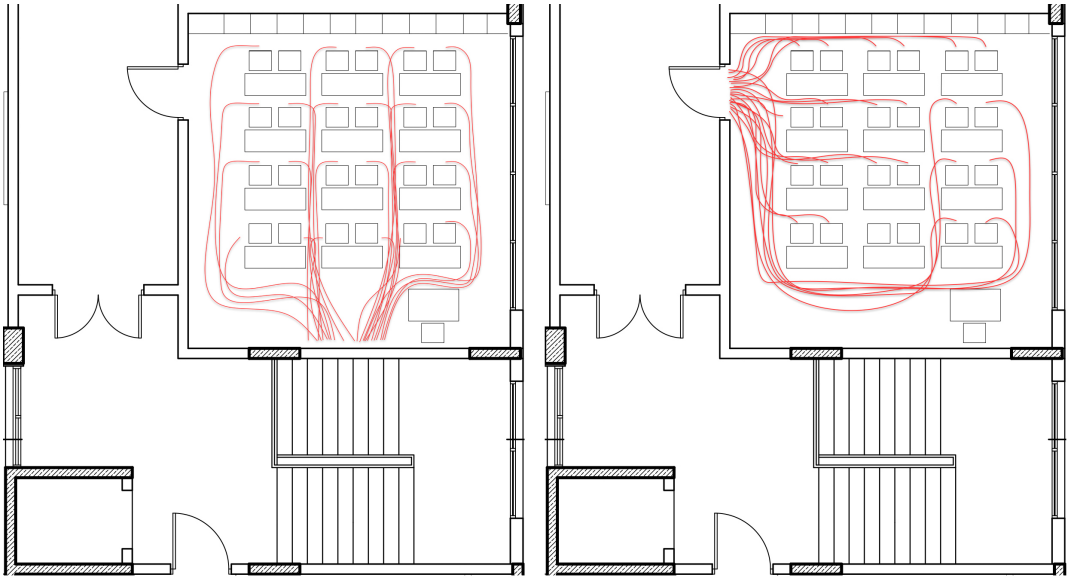

Figure 7.4: Floor plans illustrating the hypothetical trajectories of students (fourth-grade classroom).

The creation of the heat maps results in the analysis of the motion density in space. The red areas represent the higher density of movement as in the previous classroom. Similarly, to the third-grade classroom, higher density is apparent in the area closer to the board during a course, and during break time, there is a higher concentration closer to the door.

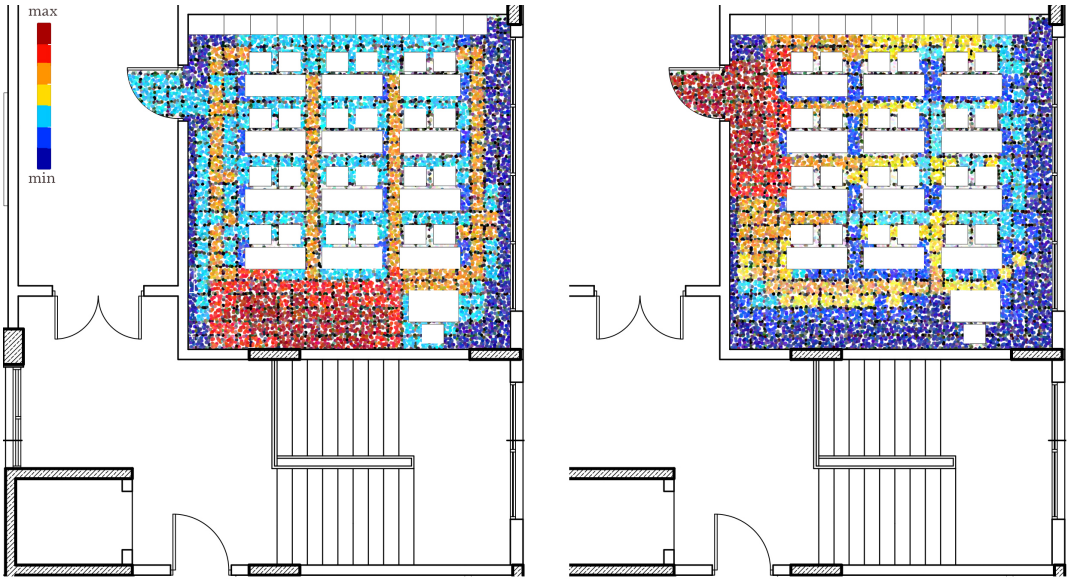

Figure 7.5: Heat maps illustrating the movement density in space (fourth-grade classroom).

7.1.2 Points of interest, lines and shapes

The first step in spatial analysis revealed the points of interest under two different activities in the classroom. These points are defined by the density of motion indicating each activity. In both classrooms, the points of interest are the same based on the hypothetical movement in space.

The first row of sketches depicts the areas of interest of the third-grade classroom, which are the areas around the board and the door. These areas are the dominant elements in space symbolising the teaching activity, which occurs in the classroom and the activities that take place outside of the classroom, such as break time.

Figure 7.6: Points of interest of the third-grade classroom.

The second row of sketches illustrates the points of interest in the fourth-grade classroom. The areas are the same as stated above, based on the previously analysed movement in space. The area around the board and the door are again the dominant elements. The comparison of these sketches results in a clear distinction regarding the layout of the elements in the classrooms. Therefore, the geometry and shapes of these four areas are similar. The dominant shapes are solid rectangles and squares. The geometry of these elements will be fundamental for the pattern creation since they can potentially act as signs in space.

Figure 7.7: Points of interest of the fourth-grade classroom.

7.1.3 Colour in space

The next step in the process is the use of colour in the classroom. Colour is an essential factor of the perceived atmosphere which also affects spatial perception. The investigation of the existing colour palette is also essential for lighting since the properties of colours, such as saturation and hue, also affect the used lighting in space. The used colours synthesise the colour palette as it is shown below each photo; therefore, the investigation is focused primarily on the tones found in the points of interest mentioned above.

Figure 7.8: Colour palette in the third-grade classroom.

For the third-grade classroom, the most used colours in the space are the ochre of the

wall and the dark colour on the floor, followed by the green hue which denotes the area around the board. Additionally, there are also coloured lockers next to the door, which is the second point of interest.

The colour palette in the second classroom is similar to the third-grade in terms of wall and floor colours. There is also a coloured area around the board, indicating where the information is enclosed during the course. The difference in this classroom is the colour of the wall strip where the board and projection area are situated. There is a darker green tone compared to the third-grade. The wall where the door is located has no other elements compared to the previous situation making ochre the dominant colour in this area.

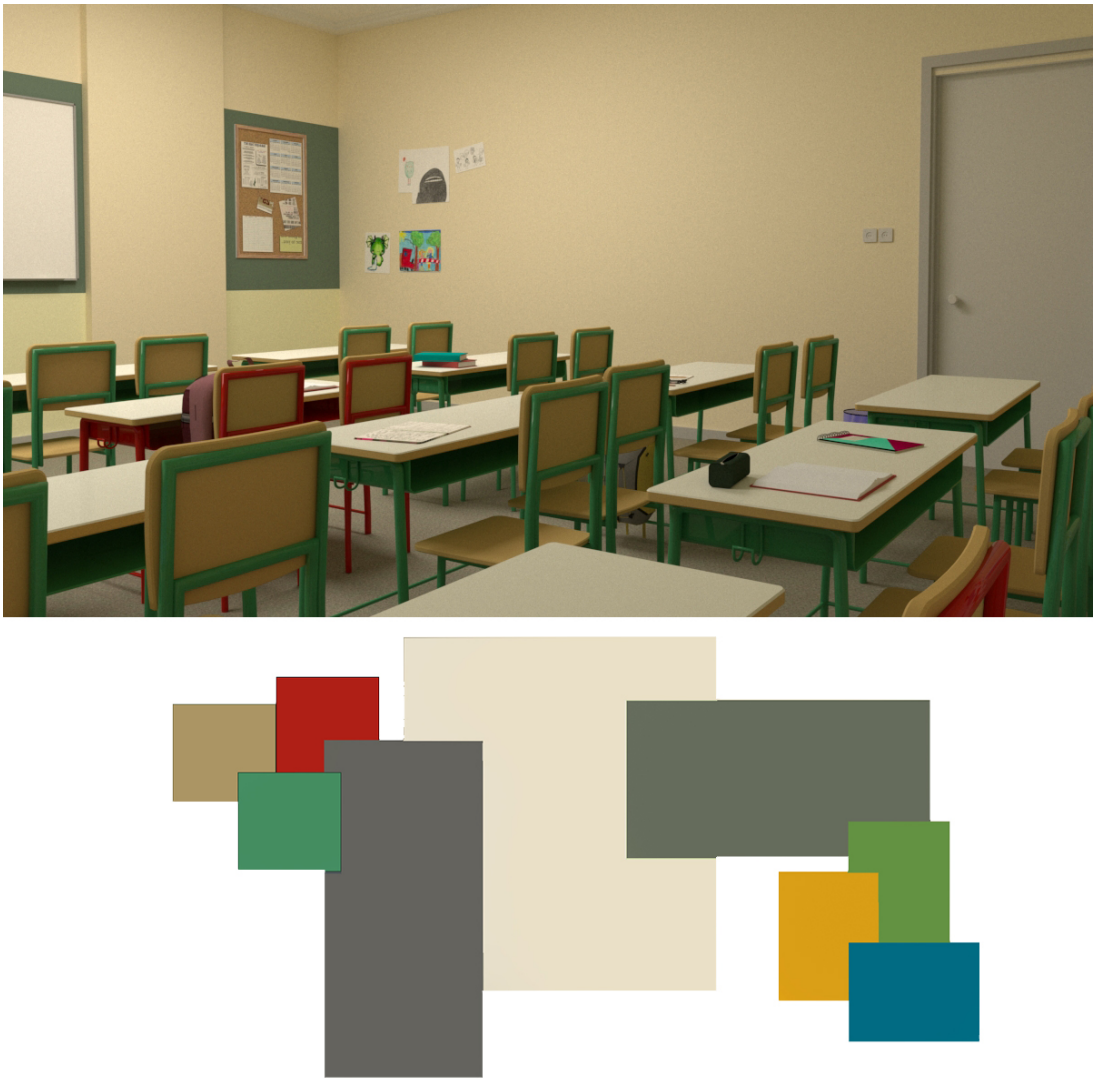

Figure 7.9: Colour palette in the fourth-grade classroom.

7.1.4 Pattern

The creation of a pattern in space is the result of all previous stages while at the same time, focuses on the element of the peripheral view as a fundamental design parameter. The initial concept is related to the users' scale leading to scaling down of one of the dominant elements in space, which is the door. This re-scaling process aims in creating a frame that is related to children's scale in terms of dimensions.

The first set of sketches addresses the pattern creation of the third-grade classroom. Through rhythmic repetition of the door's shape, a set of rectangles appears. Due to the existence of the lockers on the same wall, only a part of the pattern can be visible. The symmetrical mirror of the same pattern on the wall acts as a visible extension of its hidden part. Another element that needs to be taken into consideration is the area of information. The use of green colour delimits this area, making it stand out in space. The extension of this colour on the sidewall highlights the students' peripheral view, while they are sitting on their desks. The boards and projection area are part of the central view for the students and are also their focus area during the course. The resulting geometries from the repetition and combination of dominant elements lead in a linear light configuration that is visible in the last row of sketches.

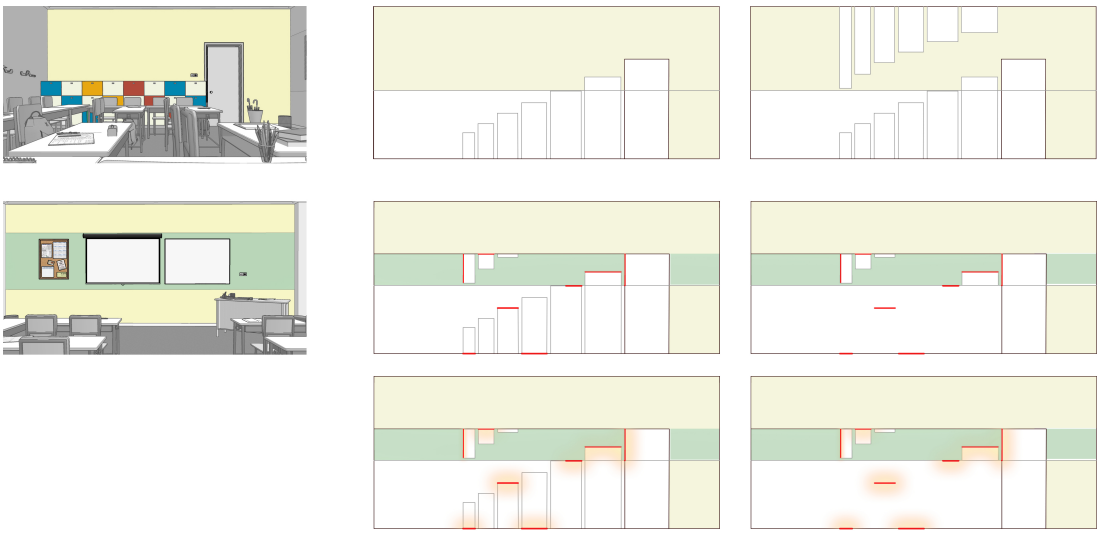

Figure 7.10: Concept sketches for third-grade classroom.

The same idea was applied in the fourth-grade classroom only in this case, the area around the door did not contain any additional elements. The same scale down process was followed, through the rhythmic repetition of the door's shape. In this case, the choice of different sides from the resulting rectangles led to three different linear light configurations. The reason only specific sides were chosen instead of whole shapes is that lines and shapes are primarily perceived in terms of spatial cognition by children. In addition to that, the pattern should not distract the users by occupying a large area of

the wall and therefore creating unnecessary contrast in space.

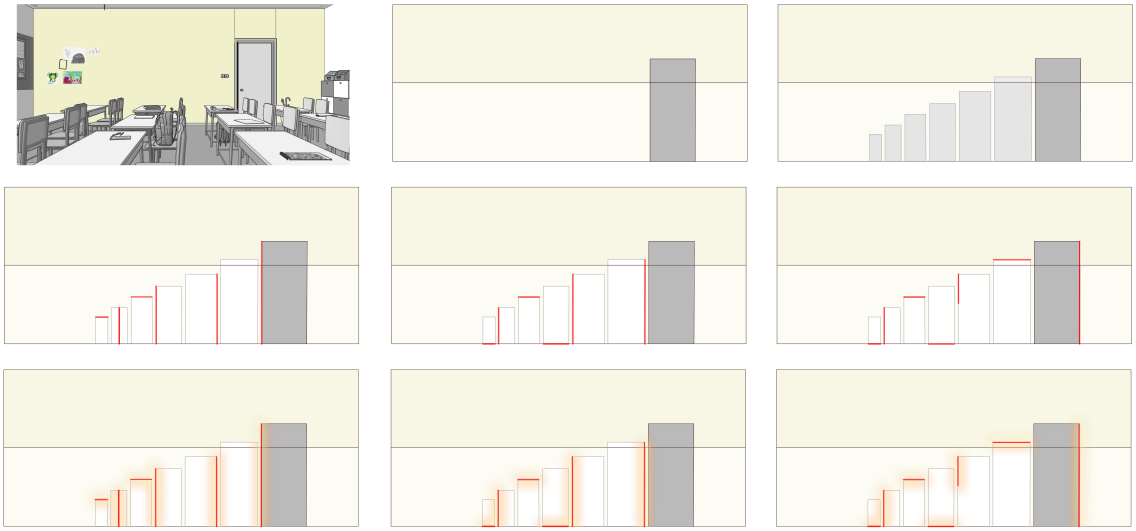

Figure 7.11: Concept sketches.

As stated previously, the second point of interest is also incorporated through the extension of the green area which surrounds and highlights students' focus. The second matrix of sketches illustrates the way that the created pattern can be used in combination with the horizontal extension of the board. For the fourth-grade classroom, the last light configuration will be further analysed as an example.

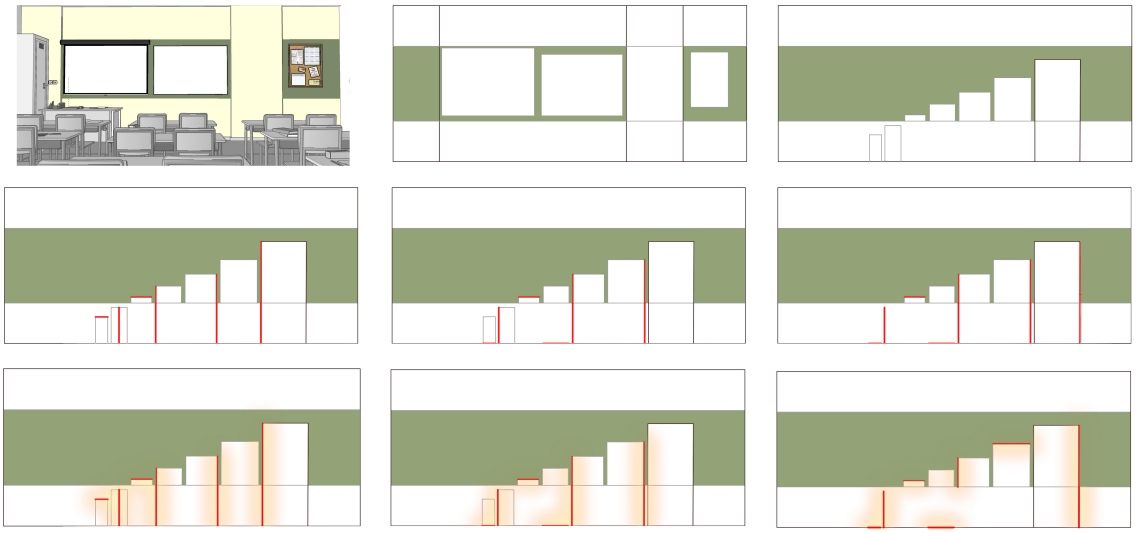

Figure 7.12: Concept sketches for fourth-grade classroom.

7.2 School schedule

The following step, after the analysis of spatial elements, is the incorporation and investigation of space's use. The purpose and use of space are mirrored in its design and follow the users' needs. The scope of this case study is an educational space; therefore, its purpose is defined by the daily schedule of each class. Based on the structure of the Greek educational system for primary schools, each grade has a main classroom, in which the majority of courses take place. The role of the primary classroom is the creation of a familiar and stable environment for the children [98].

Based on the two grades, a study of the daily schedule was performed. The goal of this investigation is to gain an insight regarding the frequency the classrooms are being used [100]. Both for the third and fourth grade the amount of courses per week is the same. There are eleven courses in total, of which five take place in different classrooms, and two of them can potentially be performed in another classroom throughout the year [99]. Depending on the schedule, the activities are divided into three different types. These types derive from the taught courses and the use of space in each case. Firstly, there are courses taught in the investigated classroom without resulting in any transitions in terms of space. Afterwards, there are courses taught in a different classroom from the investigated one, which result is a transition period between the courses. Additionally, there are courses which can occasionally be taught in another classroom, leading to a possible transition between spaces and lastly there is break time, which is the most extended type of transition.

Types of activities	Transitions
Courses taught in the main classroom.	No transition
Courses taught in **different classrooms**.	Transitions between courses.
Courses which can be taught **both** in the main and other classrooms.	Possible transition between courses.
Break time	Transition for break time. (longest)

Figure 7.13: Summary of the activities and transitions.

The mapped transitions to the schedule's courses and the different use of classrooms result in the need for the creation of three different lighting scenarios which will correspond to each transition. Every scenario will indicate the type of transition that takes place and act as an indicator of change in the space. The change in lighting will inform the children that the current activity is over, and it is the time for either a break or a different course.

7.3 Light analysis

The last part of the process is the investigation of light. In order to propose a new lighting scenario, the examination of the existing lighting is necessary. Natural light, especially for educational spaces, is a fundamental environmental factor in terms of design, being a key element and contributing both in well-being and students' performance. The current proposal does not interfere with the functional light layer, which in this case is the ceiling light, and does not eliminate or affect the natural light intake either. The first step of the analysis focuses on the understanding of the existing lighting situation.

7.3.1 Existing light in space

Natural and electric light were investigated separately in order to gain an overview of the current situation and create a proposal which does not contradict the existing light of the space. For the analysis of the natural light, the model was geolocated for having the right orientation and consequently the correct daylight intake. Four rendered images were created representing the solstices and equinoxes of the year. The time was set at 10.30 a.m for all renders.

Figure 7.14: Natural light intake, third-grade classroom.

The first set of illustration depicts the third-grade classroom. There is a minimum amount of daylight in the illustrations depicting March and September equinox, as well

as in the summer solstice illustration. According to the illustration depicting the winter solstice, there is more daylight. The creation of a light pattern at the back of the room is apparent in this case.

The following step consists of a Dialux study that represents the electric light in the classroom. According to the lighting standards and regulations, for educational spaces in Greece, the minimum lux levels should be 300 lux. In the current situation, the average lux levels are 300lux, and the levels in the working areas, which are the desks, are approximately 700lux.

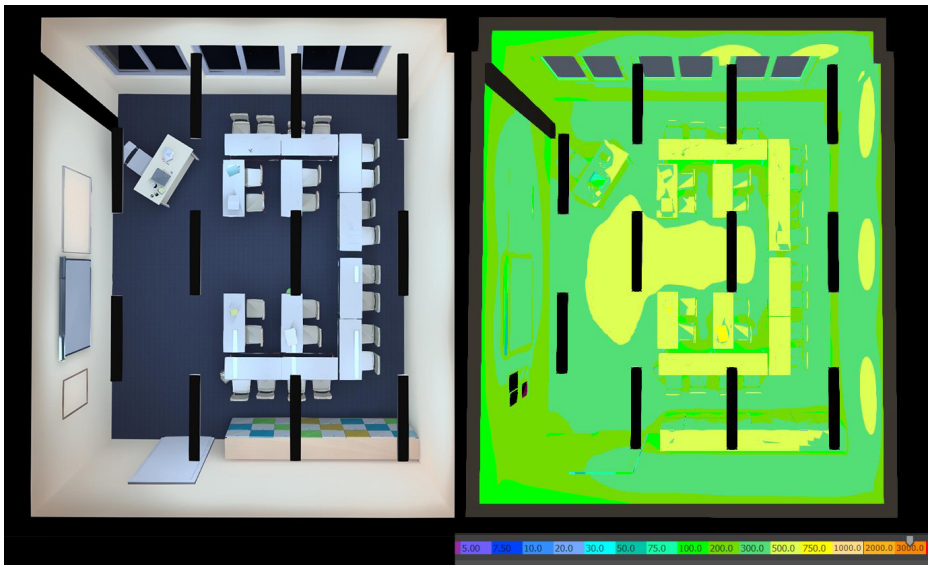

Figure 7.15: False colour representation of the light levels in the third-grade classroom.

The last illustrations of the third- grade classroom are an approximation of the amount of light during the summer and winter solstice. In these photos the electric and natural light co-exist.

Summer solstice (21/06) at 10.30 with electric light

Winter solstice (21/12) at 10.30 with electric light

Figure 7.16: Coexistence of natural and electric light in the third-grade classroom.

For the fourth-grade classroom, the same process was followed. At first, a matrix illustrating the solstices and equinoxes was made. Sunlight and daylight in this classroom are more intense than the third-grade, due to the difference in orientation. The rendered images reveal that this classroom has more daylight throughout the year. During the March and September equinox, the position of the sun is similar judging for the resulted shadows, as for the summer solstice, it seems that the elevation of the sun is higher compared to the equinoxes, and the sunlight enters a small percentage of the classroom. During the winter solstice, the sun's elevation is lower, resulting in an increased daylight intake at an earlier time of the day, since the time is set at 10.30 a.m.

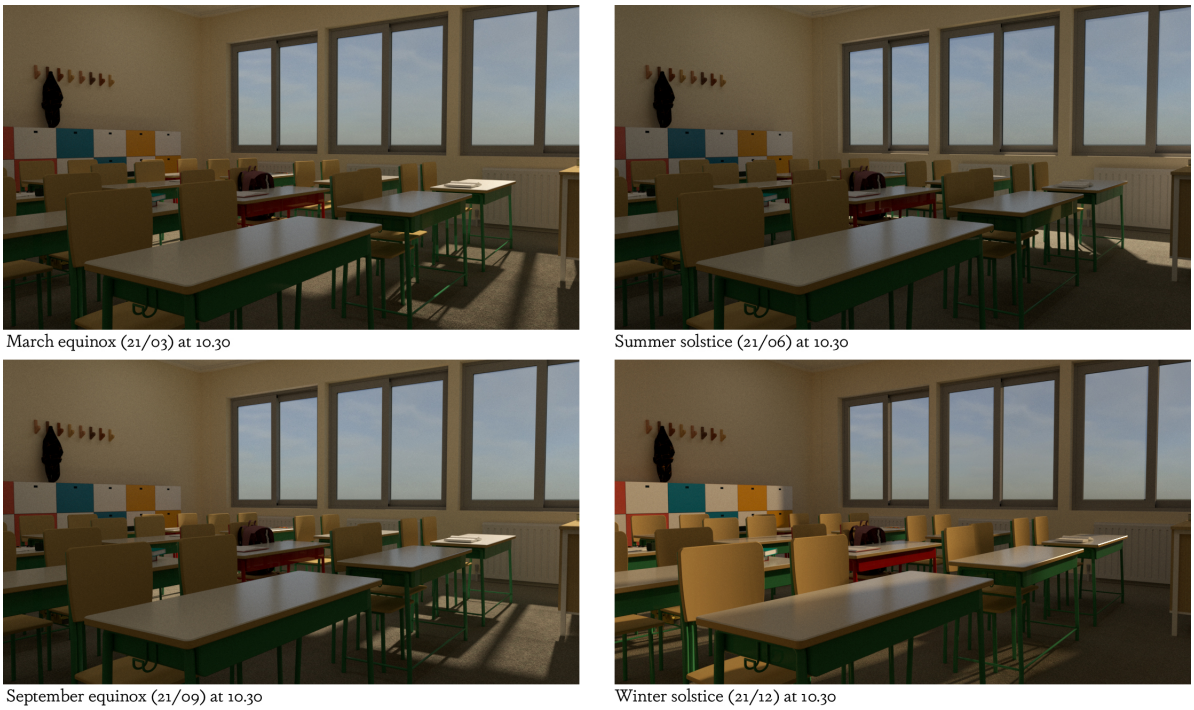

Figure 7.17: Natural light intake in the fourth-grade classroom.

Additionally, the classroom model was recreated in Dialux for the presentation of the existing light levels on behalf of the electric lights. The ceiling lights are representing the functional layer in the space. The light levels are similar to the previous classroom. The average light levels are above 300 lux, and on the working areas, the light levels are 700 lux.

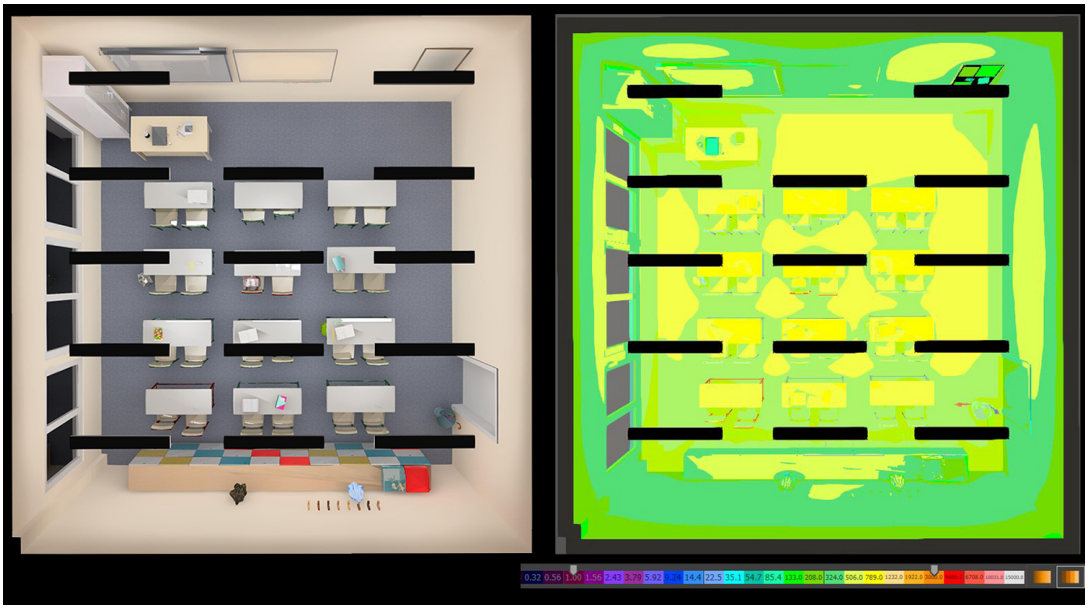

Figure 7.18: False colour representation of the light levels in the fourth-grade classroom.

The last set of illustrations gives an impression of the way the classroom appears when natural light and electric light are present in the space. The first rendered image depicts the summer solstice while the second one illustrates the winter solstice.

Summer solstice (21/06) at 10.30 with electric light

Winter solstice (21/12) at 10.30 with electric light

Figure 7.19: Coexistence of natural and electric light in the fourth-grade classroom.

Investigating the existing light was a necessary process since the goal of this proposal is the creation of an additional light layer which depends on the daily schedule but does not have a functional character in terms of task functionality and lighting standards. Hence, the profound understanding of the current atmosphere and lighting is necessary. The conclusion drawn from this step is that the two classrooms have differences regarding daylight intake, which are related to their orientation. Therefore both classrooms have a certain amount of daylight for a considerable time of the year.

The ceiling light follows the set standards for educational spaces in Greece. Consequently, the result is the creation of a stable lighting situation without changes throughout the day. The existing lighting remains the same in terms of intensity and colour temperature throughout the whole year. The current lighting is supposed to have the same intensity and colour temperature regardless of the exterior situation. The stability of the electric light levels results in the creation of functional but non-adjustable and dynamic lighting, which might as well be characterised as boring. The extra light layer aims in creating transition times, through the elements of rhythm and intensity. The proposed lighting will momentarily create contrasts in space, making it more dynamic and active. The extra light layer will be turned on only during the transition periods and not during the courses, for avoiding the creation of unnecessary contrasts.

7.3.2 Topology

The lights' placement is essential for the perceptual process and needs to be related to the peripheral view. The use of colour in the sketches defines the limits of the peripheral view. The coloured line acts as an extension of the central area within which the board is placed. Therefore, the proposed configurations in both classrooms consist of lights placed within this peripheral view area. The use of specific lights from the configurations corresponds to the three lighting scenarios according to the daily schedule analysis. As stated, the first two scenarios are related to transitions between courses while the third one will be the scenario indicating break time.

The arrangement of the proposed scenarios takes place on the wall where the door is located. Since the study focuses on the peripheral view, there are two options related to the peripheral view. A trifold of sketches illustrate the wall with the board in the middle, and on each side, the sidewalls. The lighting proposal can only be placed on the wall of the door since the second option is the wall where the windows are placed, and therefore on the height of the peripheral view, there is no open area. Furthermore, the proposal does not aim to contradict the natural light, so its placement should not be on the same side of the peripheral view as the windows.

The first set of sketches depicts the third-grade classroom. Looking at the middle sketch one can understand in which part each element is situated. The door is on the left wall while the windows are on the right side of the room. Hence the proposal will take place in the left wall.

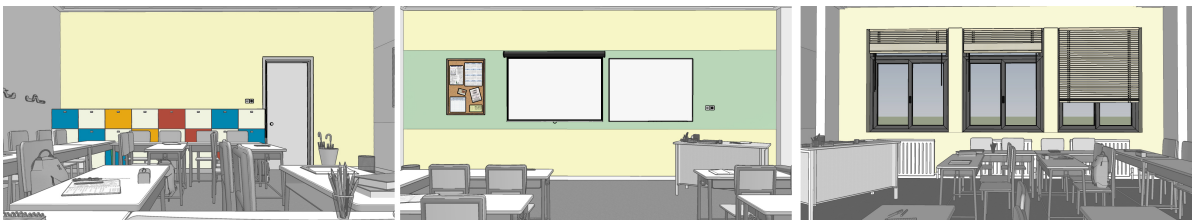

Figure 7.20: Third-grade classroom trifold.

The second row of sketches illustrates the fourth-grade classroom. The difference, in this case, is the placement of the windows, which are on the left wall compared to the previous classroom. This difference results in the proposal being placed on the right wall.

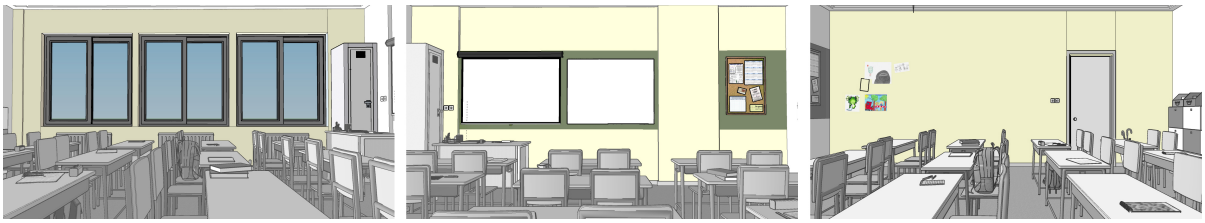

Figure 7.21: Fourth-grade classroom trifold.

Based on the activities, a different number of lights will be used as indicators. The middle area of the wall highlights the area of information in which students' attention is focused. As analysed in the pattern creation, the students' peripheral view during a course, since they sit on the desks, is the middle part of the wall, which corresponds to the height of the board. The lights placed in the middle part are to be used for transitions between courses. In contradiction to the course transition, all lights will be used to signify break time, creating a different lighting scenario.

In the following sketches, the two scenarios are depicted. The first sketch depicts the area of application, while the second one shows which lights will turn on as an indication of break time. The last sketch illustrates that only the lights placed on the height, that is an extension of the board will turn on for transitions between the courses. The choice of different lights for each scenario is also linked to the available time frame for each transition. The transition period between the two courses is shorter compared to the transition leading to break time.

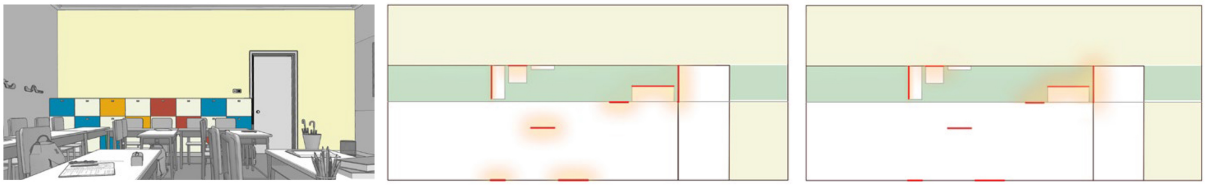

Figure 7.22: Topology of light for the third-grade classroom.

The same principle is followed for the fourth-grade classroom. The second sketch addresses the break time scenario, while the last sketch illustrates the course transition. The number of used lights under the scenario addressing course transitions is reduced since only four out of seven lights are used.

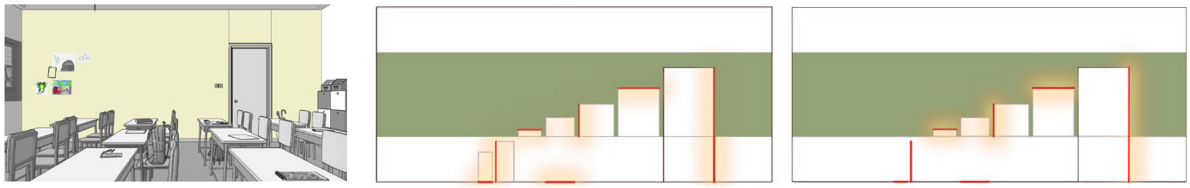

Figure 7.23: Topology of light for the fourth-grade classroom.

The following renders are an approximation of the way the peripheral view perceives the proposed light configurations. For their production, a camera with a field of view similar to the human eye was used in order to extend the rendered frame. The area that is in colour indicates the peripheral view. The renders were produced for three different positions for each classroom. In the illustrations, the lights' placement is primarily perceived by the peripheral field of view following the set success criteria.

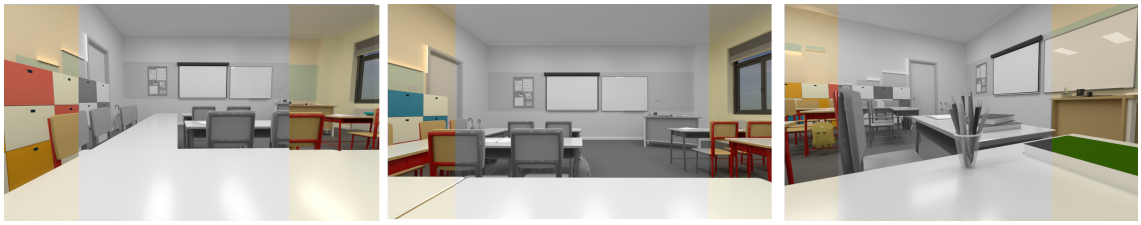

Figure 7.24: Render illustrating the central and peripheral view in the third-grade classroom.

Figure 7.25: Render illustrating the central and peripheral view in the fourth-grade classroom.

7.3.3 Colour and rhythm

The last step in the light investigation is related to the use of colour and rhythm as light variables. Apart from the placement and number of used lights for each scenario, the rhythm and intensity are valuable indicators for the proposal. The colour temperature of the light configurations will be stable. For the produced renders the colour temperature was set in 3500K and kept the same. The proposed variables are the lights' intensity and rhythm. Changes in intensity and movement are primarily perceived by peripheral vision, making them valuable variables.

Before the description of the matrices presented above a summary of the needed lighting scenarios is necessary. According to the schedule, three types of transitions take place:

- Break time
- Change of used space due to change of course.
- Occasional change of used space due to the course.

These transitions correspond to three different lighting scenarios. The following table summarises the differences between the scenarios indicating the rhythm and number of lights used in each case. The rhythm and intensity changes of the lights also differ. The first scenario which corresponds to break time has the slowest rhythm, while at the same time all light fixtures are used. The second scenario indicates the transition between courses which require a change of classroom. In this case, the rhythm is moderate, and a limited number of the lighting fixtures is used. The last scenario is related to the occasional change of classroom for some courses. This scenario has the fastest rhythm, and a reduced number of lights are used in this case, similar to the previous scenario.

For all three scenarios, the direction of this "light movement" aims at the door. The conveyed message in all cases is that a different space from the current classroom needs to be used. The light acts as an indicator of change and a guide at the same time in space.

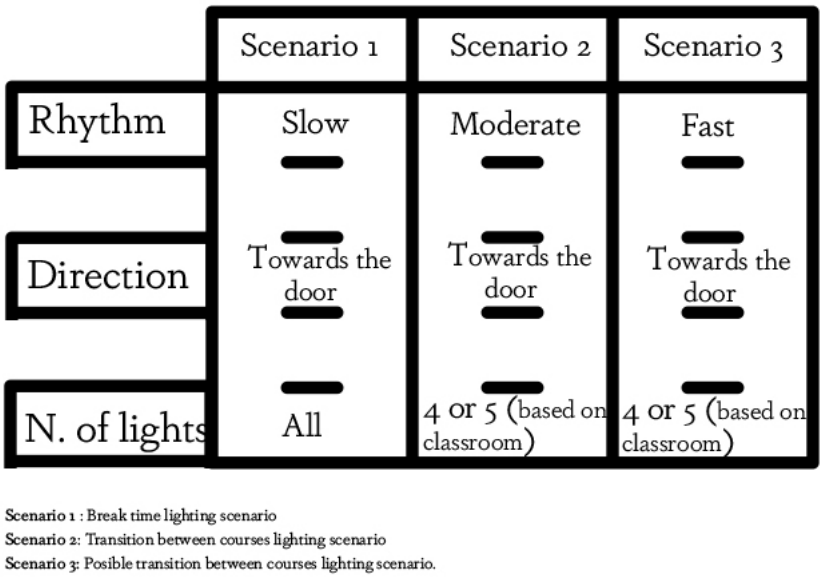

Figure 7.26: Table illustrating the three lighting scenarios.

The following matrix illustrates the way lights turn on one after another, following a direction that leads to the door. The lights symbolise the movement towards a different space. This series of rendered images illustrates the first lighting scenario. Hence all the lights eventually are turned on in the last image.

Figure 7.27: Used lights under the break scenario, for third-grade.

This series of renders may correspond to both the second and third scenarios since it is not possible to illustrate how fast the light turns on by using still images. In these cases, only the lights that are on the same height as the board area turn on. The difference between the two scenarios is the rhythm, which, as stated above, is faster in the third scenario, meaning that the lights turn on one by one within a shorter period.

Figure 7.28: Used lights under the course scenario, for third-grade.

The same changes in rhythm and number of light fixtures were followed for the fourth-grade classroom as well. The following rendered images illustrate how the lights turn on directing the user towards the door. All the lights are being used as an indication of break time.

Figure 7.29: Used lights under the break scenario, for the fourth-grade classroom.

The last series of illustrations shows the second and third scenario, as well. The number of lights, in this case, is also reduced, although the way lights direct the user remains the same. In this case, the rhythm also differs as the last lighting scenario has the fastest rhythm.

Figure 7.30: Used lights under the course scenario, for the fourth-grade classroom.

Chapter 8

Alternative proposals

The available proposal for each grade is affected by the use of colour; therefore, three alternative proposals are presented for each classroom. The design of the light configurations remains the same, and the alternative design relates to the existence of colour in space. Colour affects light perception since every colour has a different effect in terms of reflectance and light absorption. Additionally, colour and light are also linked to spatial perception, since the amount, saturation and placement of colour in space might create an altered impression in terms of brightness and spaciousness. Based on the colour's quantity in space and the amount of time it is present in the field of view, the users' perception is adjusted [84].

The creation and presentation of alternative design solutions are necessary in order to meet the different needs of the space. Furthermore, it is an integral part of the design process having alternative proposals to be evaluated by the future users of the space itself. The colour as it has already been mentioned is an intangible and fluid element that cannot be treated in the same way since it depends on the individual spatial elements of each case.

The following renders illustrate the three alternatives regarding the third-grade classroom. In all cases, the lights' parameters were the same. The directionality of the light was set to 0.4. The colour temperature was to 3500 lux, and the intensity was the same for all lights. In the first render, the rectangles formed by the light fixtures are coloured while the second approach is the use of colour as an extension of the board area, surrounding the light—the third option is the proposal of the light configuration without additional elements of colour.

By comparing the three alternatives, one can see the different impression space might give. In the first rendered image, the light appears brighter compared to the second and third since the use of the specific tone of colour enhances light's appearance and perceived intensity. The use of colour in the second rendered image might seem excessive, even though its tone and saturation do not create unnecessary contrasts with the existing palette; as for the last render, it is more subtle since the only addition is light.

Figure 8.1: Alternative no.1 for the third-grade classroom.

Figure 8.2: Alternative no.2 for the third-grade classroom.

Figure 8.3: Alternative no.3 for the third-grade classroom.

A similar use of colour was performed in the fourth-grade classroom. In the first case, the squares formed by the light were coloured. The used colour is the same as the one around the board area, which pre-existed. The second alternative is the placement of colour around the perimeter of the rectangular elements formed by light, while the third approach is the addition of light without coloured elements.

The alternatives have various spatial results based on the presence and absence of colour. The comparison of the first two illustrations, concludes in different opinions regarding the created space. In the first case, the colour gives the impression of absorbing part of the light, and even though the intensity is the same in all three cases, the lights seem more intense in the second and third image. In the second illustration, the use of colour seems a bit distracting, even though it has the same saturation as the colour that already exists around the boards. This impression might be apparent due to the saturation and hue of this particular colour. In the last rendered image, even though there is no colour added, the space is different, and due to the fact of no existing elements on this wall, there is a flow of light that creates balance without seeming incomplete or empty.

Figure 8.4: Alternative no.1 for the fourth-grade classroom.

Figure 8.5: Alternative no.2 for the fourth-grade classroom.

Figure 8.6: Alternative no.3 for the fourth-grade classroom.

Chapter 9

Discussion and future work

The focus of this study was the investigation and implementation of lighting as an indicator of change in space. Following one of the essential biological needs for light that is related to time orientation, electric light needs to be designed accordingly [15] [48].

The element of light in this study becomes a visual component aiming in creating a dialogue between space and its users. Previous research revealed that visual elements are extensively used in education since they are immediate to understand, and the conveyed information is engraved in children's memory [31]. The literature review created the desired theoretical basis, which relied on human-scale, spatial cognition and peripheral vision as domains affecting light perception. The combination of the analysis deriving for the various scientific fields resulted in the proposed design framework. The development of this theoretical set of tools for spatial and light analysis led to its theoretical application in a primary school. This school was used as a case study since physical tests and observations were not possible during this time frame.

The resulted design proposals were illustrated through the use of 3D software, and their evaluation depended on the set criteria and design directions. The role of this extra light layer was the creation of transition periods between activities. The lights were turned on only during the transition periods, based on the daily schedule. The height and topology of the proposed light configurations followed children's peripheral view and scale. The lights' intensity created momentarily contrasts suggesting activity changes in space. The colour temperature and directionality of the light fixtures remained stable in all three proposed cases. It is worth discussing the interesting facts revealed by the application of the design framework. The design methodology results in multiple suggestions allowing both the designer and the future user to evaluate and choose the solution that best fits the space.

In addition to the presented results, the limitation regarding physical tests and direct observations unveiled some variables which require further testing. One of these variables is the lights' colour temperature. The set CCT was 3500K, though it needs to be further investigated whether the colour temperature should change based on the

time of day or season and if this change is perceivable or not. Furthermore, another aspect that is not analysed is the exact time frame of each transition period. For this variable, an actual experiment needs to be designed. The experiment needs to focus on the appropriate interval for each lighting scenario. The proposal of two or more periods within which the lights gradually turn on having the same intensity, can be presented in the peripheral field of vision and then evaluated in terms of perception and annoyance. Finally, the intensity of the proposed light should also be further analysed in terms of contrast under different weather conditions. For instance, in the case of sunny weather, the sunlight is more intense. Therefore, the overall impression of the space is brighter, and the light configuration should also have a higher intensity. On a cloudy or rainy day, the intensity value cannot be the same since it might result in visual discomfort.

The overall outcome is that the presented framework results in multiple configurations allowing their evaluation both by the designer and the future users, engaging them to participate in the process.

Chapter 10

Conclusion

This thesis aimed in the implementation of light as a visual component in interior space, to enhance time orientation. The way messages are conveyed through visual languages was the leading point in the development of lighting design. This design acted as a basis for the establishment of a dialogue between the space and its users. The analysis of spatial elements combined with the investigation of the existing lighting situation in the space was the foundation for the development of design proposals. A set of tools was proposed and then applied in a case study, to result in multiple design solutions. The use and activities taking place in the investigated space acted as a framework for the definition of the required lighting scenarios which needed to be implemented. The elements of human scale and peripheral vision were the guidelines of the design proposal. The resulted design was an additional light layer, following the daily schedule and indicating the change in spatial activities throughout the day. The proposed light was designed following the users' scale, while at the same time acted as an ambient clock indicating the passage of time.

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List of Figures

Appendix A

Sun paths

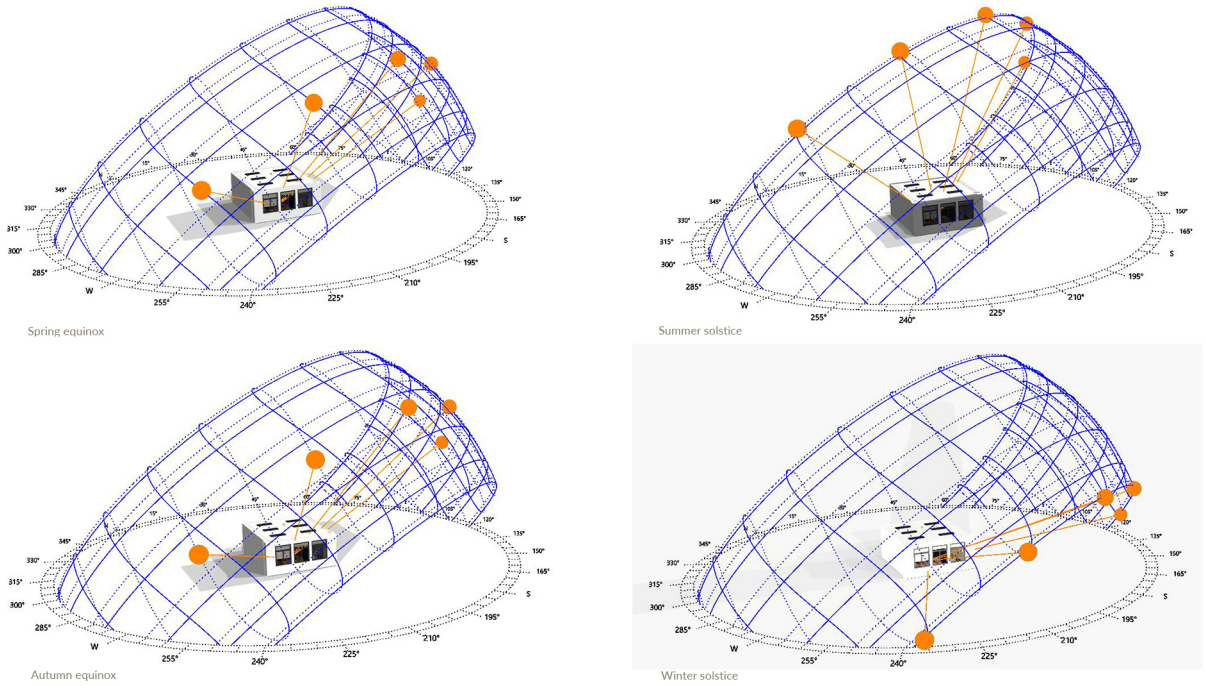

Figure A.1: Sun paths created for the third-grade classroom.

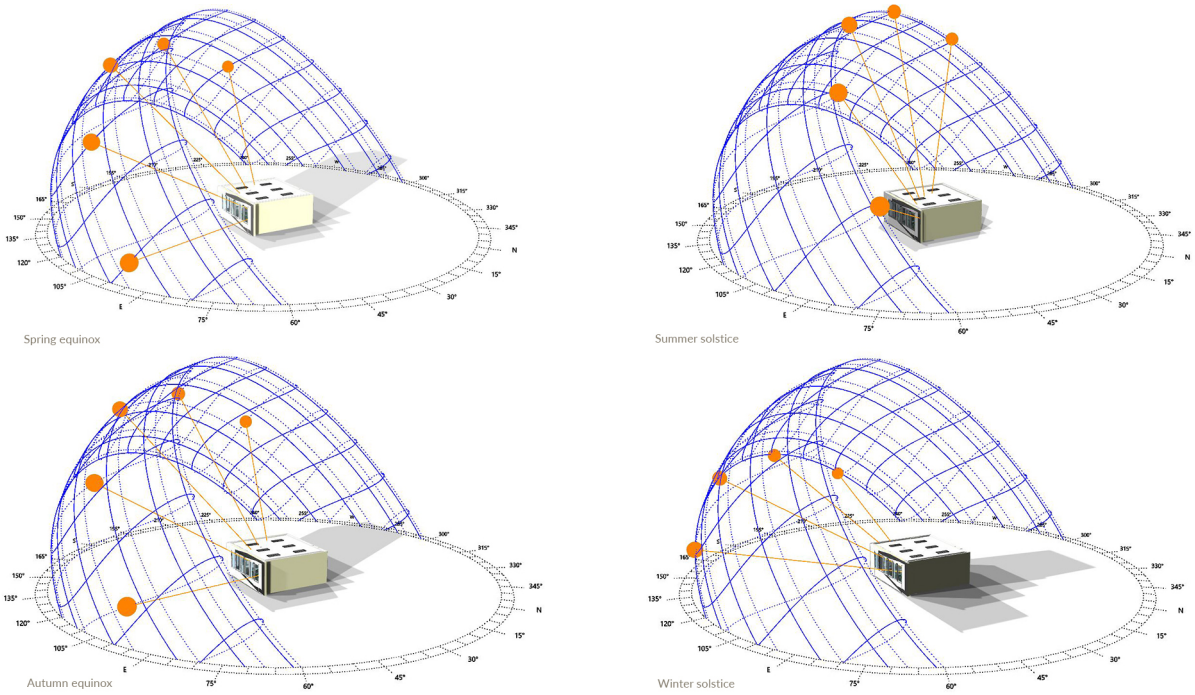

Figure A.2: Sun paths created for the fourth-grade classroom.